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## METHODS AND COMPOSITIONS FOR IMPAIRING MULTIPLICATION OF HIV-1

### CROSS-REFERENCE TO OTHER INVENTIONS

This is a divisional of U.S. Patent Application No. 09/451,067, filed November 30, 1999, which is a divisional of U. S. Patent Application No. 09/113,921, filed July 10, 1998, now U. S. Patent No. 6,193,981, issued February 27, 2001, which is a continuation-in-part of United States patent application No. 08/893,853, filed July 11, 1997, now U. S. Patent No. 5,891,994, issued April 6, 1999.

### BACKGROUND OF THE INVENTION

The present invention relates generally to compositions and methods useful for inhibiting the multiplication of human immunodeficiency virus-1 (HIV-1) in infected patients, symptomatic or asymptomatic, and for attenuating HIV-1 multiplication during primary infection in previously uninfected subjects, thus minimizing progression to AIDS.

High plasma levels of human immunodeficiency virus type 1 (HIV-1) RNA are found during primary infection with HIV-1, the seroconversion illness, (C. Baumberger *et al*, AIDS, 7:(suppl 2):S59 (1993); M. S. Saag *et al*, Nature Med., 2:625 (1996)), after which they subside as the immune response controls the infection to a variable extent. Post seroconversion, lower but detectable levels of plasma HIV-1 RNA are present, and these levels rise with disease progression to again attain high levels at the AIDS stage (M. S. Saag *et al*, Nature Med., 2:265 (1996)). Approximately 50% of subjects have a symptomatic illness at seroconversion (B. Tindall and D. A. Cooper, AIDS, 5:1 (1991)) and symptomatic seroconversion is associated with an increased risk for the development of AIDS, probably because a severe primary illness is likely related to an early and extensive spread of HIV.

Inhibition of viral multiplication during the initial infection will likely reduce the subsequent development of chronic viremia leading to AIDS. Current medical practice, with administration of antiviral drugs for defined "at risk" situations,

such as needle sticks with contaminated blood or pregnancy in HIV infected mothers, supports this concept.

Post seroconversion levels of HIV-1 RNA in plasma have proven to be the most powerful prognosticator of the likelihood of progression to AIDS (J. W. Mellors *et al*, *Science*, 272:1167 (1996); M. S. Saag *et al*, *Nature Med.*, 2:265 (1996); R. W. Coombs *et al*, *J. Inf. Dis.*, 174:704 (1996); S. L. Welles *et al*, *J. Inf. Dis.*, 174:696 (1990)). Other measures of viral load, such as cellular RNA (K. Saksela *et al*, *Proc. Natl. Acad. Sci. USA*, 91:1104 (1994)) and cellular HIV proviral DNA (T-H. Lee *et al*, *J. Acq. Imm. Def. Syndromes*, 7:381 (1994)) similarly establish the importance of the initial infection in establishing viral loads that determine future disease progression.

Thus, any intervention that inhibits HIV-1 infectivity during initial infection and/or lowers viral load post sero-conversion is likely to have a favorable influence on the eventual outcome, delaying or preventing progression to AIDS.

A variety of methods are now employed to treat patients infected with human immunodeficiency virus (HIV-1), including treatment with certain combinations of protease inhibitor drugs. Unfortunately, however, this type of treatment is associated with serious side effects in some patients. Alternatively, vaccines are under development for control of the spread of HIV-1 to uninfected humans. However, this effort has largely been directed to proteins of the virus, expressed on the surface of infected cells, which are recognized by cytotoxic T cells with elimination of the infected cells, while free virus is blocked and cleared by antibody to surface antigens of the virion. Limitations of this mode of vaccination are readily apparent for HIV-1, which has demonstrated a great diversity in immunogenic viral epitopes and rapid mutational variations that occur within and between individuals (B. D. Preston *et al*, *Science*, 242:1168(1988); J. D. Roberts *et al*, *Science*, 242:1171 (1988); A. R. Meyerhans *et al*, *Cell*, 58:901 (1989); K. Kusumi *et al*, *J. Virol.*, 66:875 (1992); B. A. Larder *et al*, *Science*, 243:1731 (1989); M. S. Sang *et al*, *N. Engl. J. Med.*, 329:1065 (1993); M. A. Sande, *et al*, *JAMA*, 270:2583 (1993); M. Seligmann *et al*, *Lancet*, 343:871 (1994); G. Meyers *et al*, *Human retroviruses and AIDS 1993, I-V*.

*A compilation and analysis of nucleic acid and amino acid sequences.* Los Alamos National Laboratory, Los Alamos, NM.)

Variation in strains of HIV-1 and frequent mutations of virion proteins have prevented successful application of conventional vaccine approaches (W. E. Paul, 5 *Cell*, 82:177 (1995); J. E. Osborn, *J. Acq. Imm. Def. Syndr. Hum. Retrovirol.*, 9:26 (1995)). Mutation and selection of resistant variants is the central problem in developing a successful HIV-1 vaccine (M. D. Daniel et al., *Science*, 258:1938 (1992); N. L. Letvin, *N. Engl. J. Med.*, 329:1400 (1993); M. Clerici et al., *AIDS*, 8:1391 (1994); S. M. Wolinsky et al., *Science*, 272:537 (1996)).

10 Other approaches to HIV-1 treatment have focused on the transactivating (*tat*) gene of HIV-1, which produces a protein (Tat) essential for transcription of the virus. The *tat* gene and its protein have been sequenced and examined for involvement in proposed treatments of HIV (see, e.g., U. S. Patent No. 5,158,877; U. S. Patent No. 5,238,882; U. S. Patent No. 5,110,802; International 15 Patent Publication No. WO92/07871, published May 14, 1992; International Patent Publication No. WO91/10453, published July 25, 1991; International Patent Publication No. WO91/09958, published July 11, 1991; International Patent Publication No. WO87/02989, published May 21, 1987). Tat protein is released extracellularly, making it available to be taken up by other infected cells to enhance 20 transcription of HIV-1 in the cells and to be taken up by noninfected cells, altering host cell gene activations and rendering the cells susceptible to infection by the virus. Uptake of Tat by cells is very strong, and has been reported as mediated by a short basic sequence of the protein (S. Fawell et al., *Proc. Natl. Acad. Sci., USA*, 91:664-668 (1994)).

25 International Patent Publication No. WO92/14755, published September 3, 1992, relates to the Tat protein and to the integrin cell surface receptor capable of binding to the Tat protein. Two Tat sequences that bind integrin are identified, which are the basic region or domain which is the dominant binding site for the integrin, having a peptide sequence of -Arg-Lys-Lys-Arg-Arg-Gln-Arg-Arg-Arg- 30 (SEQ ID NO: 4), as well as -Gly-Arg-Gly-Asp-Ser-Pro- (SEQ ID NO: 5). This

specification demonstrates that a number of peptides corresponding to these Tat sequences and the corresponding integrins block *in vitro* cell binding to Tat coated plates, as do antibodies to the appropriate integrins. However, the specification also shows that these reagents do not block uptake of functional Tat by cells (see Example 9 in WO92/14755), thus nullifying the proposed mechanism of action for therapeutic benefit in HIV infection. The Tat sequences described in this international application are distinct from the peptide immunogens of the present invention.

Both monoclonal and polyclonal antibodies to Tat protein have been readily produced in animals and shown to block uptake of Tat protein *in vitro* (see, e.g., D. Brake et al, J. Virol., 64:962 (1990); D. Mann et al, EMBO J., 10:1733 (1991); J. Abraham et al, cited above; P. Auron et al, cited above; M. Jaye et al, cited above; G. Zauli et al, cited above). More recent reports showed that monoclonal or polyclonal antibodies to Tat protein added to tissue culture medium attenuated HIV-1 infection *in vitro* (L. Steinaa et al, Arch. Virol., 139:263 (1994); M. Re et al, J. Acq. Imm. Def. Syndr. Hum. Retrovirol., 10:408 (1995); and G. Zauli et al, J. Acq. Imm. Def. Syndr. Hum. Retrovirol., 10:306 (1995)).

The inventor's own publication (G. Goldstein, Nature Med., 2:960 (1996); see also, International Patent Publication No. WO95/31999, published November 30, 1995) reviewed the evidence indicating that secretion of HIV-1 Tat protein from infected cells and uptake by both infected and uninfected cells was important for the infectivity of HIV-1. Previous studies also showed that antibodies to Tat protein *in vitro* blocked uptake of Tat and inhibited *in vitro* infectivity. Goldstein proposed active immunization of mammals to induce antibodies to HIV-1 Tat protein as a potential AIDS vaccine.

Despite the growing knowledge about HIV-1 disease progression, there remains a need in the art for the development of compositions and methods for treatment of HIV-1, both prophylactically and therapeutically, which are useful to lower the viral levels of HIV-1 for the treatment and possible prevention of the subsequent, generally fatal, AIDS disease.

## SUMMARY OF THE INVENTION

In one aspect, the invention provides as a novel composition comprising a peptide or polypeptide, which comprises an amino acid sequence selected from the formula referred to as Epitope I: R1-Val-Asp-Pro-Y-Leu-Glu-Pro-R2 (SEQ ID NO: 36), wherein Y is variously Arg, Lys, Ser or Asn. The N-terminal R1 may represent hydrogen (i.e., the hydrogen on the unmodified N terminal amino acid), or a lower alkyl, or a lower alkanoyl. R1 may also include a sequence of between 1 to about 5 amino acids, optionally substituted with a lower alkyl or lower alkanoyl. In one embodiment, R1 is -X-Pro-, wherein X is Glu or Asp. Preferably, R1 represents 2 amino acids. The C-terminal R2 can also represent the hydroxyl group on the C terminal amino acid or an amide. To enhance titer R2 is preferably a sequence of between 1 to about 14 additional amino acids amidated at the carboxyl terminus. In a preferred embodiment, R2 is -Trp-Lys-His-Pro-Gly-Ser- amide (SEQ ID NO: 10). The peptides or polypeptides of these compositions are produced synthetically or recombinantly. This composition may take the form of one or more of the above-described peptides expressed as a synthetic peptide coupled to a carrier, or expressed as a multiple antigenic peptide, or the selected peptides may be expressed within a recombinantly produced protein. This composition is designed to induce antibodies reactive with greater than 95% of the known variants of the HIV-1 Tat protein.

In another aspect, the above-described composition further contains one or more additional peptide or polypeptide(s) which represent other amino acid sequences which correspond to amino acid residues 2 or 4 to 10 of an HIV-1 Tat protein. These optional amino acid sequences are described in detail below. These sequences are preferably from an HIV-1 strain with a Tat protein variant at that location.

In another aspect, the invention provides a novel composition comprising a peptide or polypeptide of the formula referred to as Epitope II: R3-Lys-X-Leu-Gly-Ile-Ser-Tyr-Gly Arg-Lys-Lys- R4 (SEQ ID NO: 37). According to this formula, X is Gly or Ala. The N terminal R3 may represent hydrogen (i.e., the hydrogen on the unmodified N terminal amino acid), or may be a lower alkyl, or a

lower alkanoyl. R3 may also include a sequence of between 1 to about 5 amino acids, optionally substituted with a lower alkyl or lower alkanoyl. The C terminal R4 may be the free hydroxyl of the C terminal amino acid, or an amide, or a sequence of one or up to about 5 additional amino acids, optionally substituted with an amide. The peptides or polypeptides of these compositions are produced synthetically or recombinantly, provided that the recombinant Epitope II peptide is situated at the C terminus of the recombinant protein. This composition may take the form of one or more of the above-described peptides expressed as a synthetic peptide coupled to a carrier, or expressed as a multiple antigenic peptide. This composition is designed to induce antibodies reactive with greater than about 95% of the known variants of HIV-1 Tat protein.

In yet a further aspect, this invention provides a composition comprising a peptide or polypeptide of the formula referred to as Epitope III: R5-Arg-Arg-X-Z-A-Y-Ser-R6 (SEQ ID NO: 38), wherein X is selected from the group consisting of Ala, Pro, Ser and Gln; wherein Y is selected from the group consisting of Asp, Asn, Gly and Ser; wherein Z is selected from the group consisting of Pro and His; and wherein A is selected from the group consisting of Gln and Pro. The N terminal R5 is hydrogen, a lower alkyl, a lower alkanoyl, or a sequence of between 1 to about 3 amino acids, optionally substituted with a lower alkyl or lower alkanoyl. In a preferred embodiment R5 is -Gln-Arg-, optionally modified as above. The C terminal R6 is either a free hydroxyl or an amide. A preferred embodiment of such a composition contains at least three Epitope III peptides, i.e., -Gln-Arg-Arg-Arg-Ala-Pro-Gln-Asp-Ser- (amino acids 54-62 of SEQ ID NO: 1), -Gln-Arg-Arg-Arg-Ala-His-Gln-Asp-Ser- (amino acids 2-10 of SEQ ID NO: 65), and -Gln-Arg-Arg-Arg-Ala-Pro-Pro-Asp-Ser- (amino acids 264-272 of SEQ ID NO: 3), optionally modified as above. Other peptides or polypeptides representative of amino acids 56-62 of Tat, but having different sequences from that of the above formula may also be included in the composition. The peptides or polypeptides of these compositions are produced synthetically or recombinantly. This composition may take the form of one or more of the above-described peptides expressed as a synthetic peptide coupled to a carrier, or

expressed as a multiple antigenic peptide, or the selected peptides may be expressed within a recombinantly produced protein. This composition is designed to induce antibodies reactive with greater than about 75% of all known variants of HIV-1 Tat protein.

5 In still a further aspect, this invention provides a composition comprising a peptide or polypeptide of the formula referred to as Epitope IV: R7-Ser-Gln-X-His-Gln-Y-Ser-Leu-Ser-Lys-Gln-Pro-R8 (SEQ ID NO: 39), wherein X is selected from the group consisting of Asn and Thr; and wherein Y is selected from the group consisting of Ala and Val. The N terminal R7 may be hydrogen, a lower  
10 alkyl, a lower alkanoyl, or a sequence of between 1 to about 3 amino acids, optionally substituted with a lower alkyl or lower alkanoyl. The C terminal R8 may be a free hydroxyl, an amide, or a sequence of one or up to about 3 additional amino acids, optionally substituted with an amide. A preferred Epitope IV peptide is -Ser-Gln-Thr-His-Gln-Ala-Ser-Leu-Ser-Lys-Gln-Pro- (SEQ ID NO: 40). The peptides or  
15 polypeptides of these compositions are produced synthetically or recombinantly. This composition may take the form of one or more of the above-described peptides expressed as a synthetic peptide coupled to a carrier, or expressed as a multiple antigenic peptide, or the selected peptides may be expressed within a recombinantly produced protein. This composition is designed to induce antibodies reactive with  
20 greater than 64% of all known variants of HIV-1 Tat protein.

In still another aspect, this invention provides composition described above that contains peptides or polypeptides which comprise one or more Epitope I peptides in combination with one or more Epitope II peptides, and/or one or more Epitope III peptides, and/or one or more Epitope IV peptides. Such compositions can  
25 combine appropriate Epitope peptides, so as to provide for a composition than induces antibodies reactive with greater than about 99% of all known HIV-1 Tat proteins.

In yet a further aspect, the invention provides a synthetic gene which encodes sequentially a peptide or polypeptide that contains at least one Epitope I amino acid sequence defined above, optionally with a carboxy terminal Epitope II  
30 peptide, or contains at least two Epitope I amino acid sequences. The synthetic gene

may contain each amino acid sequence separated by a spacer sequence, or may express each peptide/polypeptide in an open reading frame with a carrier protein. The synthetic gene may be separated from the carrier protein by a spacer if the spacer is fused to an Epitope I sequence, leaving an Epitope II sequence at the carboxy terminus of the recombinant protein. Further embodiments include multiple Epitope I peptides fused together and to the carrier protein.

In yet a further aspect, the invention provides a synthetic molecule, e.g., a vector, comprising the above-described synthetic gene, operatively linked to regulatory nucleic acid sequences, which direct and control expression of the product of the synthetic gene in a host cell.

In another aspect, the invention provides a recombinant virus which contains the above described synthetic gene or synthetic molecule, which virus is capable of expressing multiple copies of the product of the gene or molecule in a host cell. The virus is non-pathogenic to humans.

In yet another aspect, the invention provides a commensal bacterium which contains the above described synthetic gene or synthetic molecule, which bacterium is capable of expressing multiple copies of the product of the gene or molecule and inducing antibodies in a mammalian host.

In still a further aspect, the invention provides an isolated antibody composition which is directed against a peptide or polypeptide of the compositions described above. Antibodies may also be obtained against multiple components of the compositions described above. This antibody is produced by immunizing a mammal with a peptide/polypeptide composition of the invention, a synthetic gene or synthetic molecule of the invention; a recombinant virus or commensal bacterium of the invention; and isolating and purifying antibody from said immunized mammal. Alternatively, the antibody may be a polyclonal antibody, a monoclonal antibody, a chimeric antibody, a humanized antibody, a human antibody, or mixtures thereof.

Thus, another aspect of the invention is a pharmaceutical composition useful for inducing antibodies that react with greater than 95%, and preferably greater than 99%, of the known HIV-1 Tat proteins. These induced antibodies can impair the



multiplication of HIV-1. The pharmaceutical composition comprises at least one of the recombinant or synthetic peptide/polypeptide compositions described above; the synthetic gene/molecule described above; the recombinant virus described herein; or the commensal bacterium described herein, in a pharmaceutically acceptable carrier.

5 Still a further aspect of the invention is a pharmaceutical composition useful for impairing the multiplication of HIV-1, this composition containing an above described antibody composition.

10 In yet a further aspect of the invention, a method for reducing the viral levels of HIV-1 involves exposing a human to antibody-inducing pharmaceutical compositions described above, actively inducing antibodies that react with most HIV-1 Tat proteins, and impairing the multiplication of the virus *in vivo*. This method is appropriate for an HIV-1 infected subject with a competent immune system, or an uninfected or recently infected subject. The method induces antibodies which react with HIV-1 Tat proteins, which antibodies reduce viral multiplication during any initial  
15 acute infection with HIV-1 and minimize chronic viremia which leads to AIDS.

In still another aspect, the invention provides a method for reducing the viral levels of HIV-1 by administering to a human, who is incapable of mounting an effective or rapid immune response to infection with HIV-1, a pharmaceutical composition containing the antibody compositions described above. The method can  
20 involve chronically administering the composition.

Yet other aspects of the invention include methods for producing the compositions described above, as well as host cells transfected with such compositions.

25 Still another aspect of this invention is a kit useful for the measurement and detection of titers and specificities of antibodies induced by vaccination with the compositions described above. The kit of the invention includes peptides of Epitopes I through IV, and coated solid supports, a labelled reagent for detecting the binding of antibodies to these peptides, and miscellaneous substrates and apparatus for evoking or detecting the signals provided by the labels, as well as conventional apparatus for taking blood samples, appropriate vials and other diagnostic assay components.

In yet a further aspect, the invention provides a method for detecting the titers and reactivity patterns of antibodies in subjects vaccinated with the compositions of this invention. The method includes the steps of incubating dilutions of the subject's biological fluid, e.g. serum, with plates or beads on which are bound one or more peptides of the Epitopes I through IV, washing away unbound biological materials, and measuring any antibody binding to the peptides with labeled reagent, e.g., an anti-human immunoglobulin to which is associated an enzyme. Depending on the type of label employed, the signal produced by the label may be evoked by further adding a substrate which reacts with the enzyme, e.g., producing a color change.

Other conventional labels may also be incorporated into this assay design.

Other aspects and advantages of the present invention are described further in the following detailed description of the preferred embodiments thereof.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 illustrates an HIV-1 Tat protein consensus sequence (SEQ ID NO: 1), based on Tat protein sequences of 31 known HIV-1 strains found in the common B subtype (NIH Los Alamos database). The amino acid positions in which variations appear are in lower case letters.

Figs. 2A-2C illustrate a synthetic gene which encodes a fusion protein (SEQ ID NO: 3) of this invention, described in detail in Example 5 below.

#### DETAILED DESCRIPTION OF THE INVENTION

The present invention provides a solution to the above-stated problem by providing compositions which induce antibodies in uninfected or early stage infected subjects still capable of mounting an immune response to an immunogen, the antibodies reacting with greater than 95%, and preferably, greater than 99% of known HIV-1 Tat protein variants. The induced antibodies can inhibit multiplication of HIV-1. This prevents further disease progression to AIDS. Antibody compositions are also provided for use in infected or non-infected humans, who are incapable of mounting an effective or rapid immune response to HIV-1 infection. These compositions are

capable of reacting with greater than 95%, and preferably greater than 99%, Tat proteins thus reducing viral levels of HIV-1. These antibodies are useful in both therapeutic and prophylactic contexts to control the development of AIDS in a large population exposed to, or infected by, HIV-1 strains which produce upon infection immunologically distinct Tat proteins.

The compositions of the present invention, which are based on peptides provided by certain epitopes of HIV-1 Tat protein, may be proteinaceous in nature, or may be nucleic acid compositions which encode the peptides and polypeptides that induce antibodies to Tat, which in turn impair multiplication of HIV-1.

HIV-1 Tat protein is produced from two exons: Exon 1 encodes a 72 amino acid (aa) protein (see Fig. 1, SEQ ID NO: 1) which may be expressed without splicing or be spliced with the approximately 29 amino acid peptide encoded by Exon 2 to produce an approximately 101 amino acid peptide. Since the 72 amino acid product of Exon 1 is capable alone of cellular uptake and activation, it is essential that antibodies react with and interdict intercellular transport of the 72 amino acid peptide. HIV-1 Tat contains Cys at aa positions 22 and 37 of Exon 1 (SEQ ID NOS: 1 and 2), and 5 additional Cys between these. This region of the peptide is termed the Cys rich region and has Cys-Cys covalent linkages producing complex tertiary structure. The scientific literature has indicated that this region does not appear to be immunogenic.

The inventor has identified epitopes, i.e., binding regions, recognized by antibodies (antigenic sequences) in the N-terminal linear sequence 1-21 (22 aa) and the C-terminal linear sequence 38-72 (35 aa) of Exon 1 (SEQ ID NO: 2) or other Tat sequence variants. Immunogenic regions of these larger sequences were identified by the inventor and are underlined in the N terminal and C terminal consensus sequences of Exon 1 below: Epitope I was identified as the nine amino acid sequence of aa positions 2-10 of Exon 1. Epitope II was identified as the eleven amino acid sequence of aa positions 41-51 of Exon 1. Epitope III was identified as the 7 amino acid sequence of aa positions 56-62 of Exon 1. Epitope IV was identified as the twelve amino acid sequence of aa positions 62-73 of Tat, including the the first Pro (aa 73) of Exon 2 and overlaps Ser 62 of Epitope III (dotted underlining).

1  
Met Glu Pro Val Asp Pro Arg Leu Glu Pro Trp Lys His Pro Gly Ser Gln Pro Lys Thr

21 38 41  
5 Ala (SEQ ID NO: 54) ..... Phe Ile Thr Lys Gly Leu Gly Ile Ser Tyr Gly Arg Lys

51 56 62  
10 Lys Arg Arg Gln Arg Arg Arg Ala Pro Gln Asp Ser Gln Thr His Gln Val Ser Leu  
-----  
72  
Ser Lys Gln Pro (SEQ ID NO: 55).  
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15 The term "Tat sequence variant" means a polypeptide or peptide  
containing Tat protein amino acid residues, or a sequence from another HIV-1 strain  
Tat protein that is substantially similar to the sequence of SEQ ID NO: 1. Each variant  
may differ from the consensus sequence of Fig. 1 (SEQ ID NO: 1) and/or from another  
variant by at least one amino acid change within the residues of interest for Epitopes I  
through IV. This change may provide the same or different antigenic specificity to that  
20 particular Tat Epitope when added to the composition of the invention.

#### A. *Epitope I Immunogenic Compositions*

25 Therefore, in one embodiment, the present invention provides a  
composition containing a non-naturally occurring peptide or polypeptide, which  
comprises one or more Epitope I amino acid sequences. These Epitope I sequences  
elicit a specific humoral immune response (for the purpose of this invention) in a  
mammal exposed to the Epitope I sequences *in vivo*. The Epitope I amino acid  
sequences correspond to amino acid residues 2-10 or 4-10 of the Tat consensus  
sequence (SEQ ID NO: 1) of Fig. 1 which is derived from a number of "Tat sequence  
variants".

30 Epitope I defines peptides of the general formula: R1-Val-Asp-  
Pro-Y-Leu-Glu-Pro-R2 (SEQ ID NO: 36). The N-terminal R1 may represent the  
hydrogen on the unmodified N terminal amino acid Val, or R1 may be a lower alkyl, or  
a lower alkanoyl attached to the Val. R1 may also include a sequence of between 1 to  
about 5 amino acids, optionally substituted with a lower alkyl or lower alkanoyl. In

one embodiment, R1 is -X-Pro-, wherein X is Glu or Asp. The C-terminal R2 can represent the hydroxyl group on the C terminal amino acid Pro, or R2 can be an amide on the Pro; alternatively, R2 is a sequence of between 1 to about 14 additional amino acids, optionally amidated at the carboxyl terminus. The X and Y positions represent common variants of this Epitope peptide, wherein X is Glu (90%) or Asp (10%), and Y is variously Arg (74%), Lys (11%), Ser (9%) or Asn (4%). Peptides containing Glu or Asp at position X induce antibodies that effectively cross-react with the other variant. Alternatively, peptides omitting the X-P effectively induce antibodies to Val-Asp-Pro-Arg-Leu-Glu-Pro (amino acids 4-10 of SEQ ID NO: 1). A desirable immunogen of the formula Glu-Pro-Val-Asp-Pro-Lys-Leu-Glu-Pro (SEQ ID NO: 56) reacts/cross-reacts with greater than 95% of known HIV-1 Tat proteins, while an immunogen of the formula Val-Asp-Pro-Lys-Leu-Gly-Pro (SEQ ID NO: 57) reacts/cross-reacts with greater than 97% of known HIV-1 Tat proteins.

Antibodies to all four position Y variants are generated by using all four as immunogens. Alternatively, cross-reactivity permits a reduction to two or even one immunizing sequence to induce reactivity to all four position Y variants. As discussed in detail in the Examples below, the reactivities of antibodies induced by the Epitope I-containing peptide: Val-Asp-Pro-Y-Leu-Glu-Pro-Typ-Lys-His-Pro-Gly-Ser- (SEQ ID NO: 58), where Y is Arg, Lys, Ser or Asn, are reported in Table 1 below. Dark shading shows self-reactivity, pale shading shows significant (40%) cross-reactivity.

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Table 1

Immunizing Peptides	Detector Peptides (GMT (% self-binding))			
Position Y	Arg	Lys	Ser	Asn
Arg	77,000 (100)	10,000 (13)	10,000 (13)	9,000 (12)
Lys*	51,000 (62)	82,000 (100)	35,000 (43)	45,000 (55)
Ser	8,000 (6)	8,000 (6)	128,000 (100)	14,000 (11)
Asn*	17,000 (13)	12,000 (9)	61,000 (46)	134,000 (100)

\* Only one high titer antiserum available.

Preferably a composition of this invention contains one or more of the following Epitope I peptides or polypeptides:

R1-Val-Asp-Pro-Arg-Leu-Glu-Pro-R2 (SEQ ID NO: 6);

R1-Val-Asp-Pro-Lys-Leu-Glu-Pro-R2 (SEQ ID NO: 7);

R1-Val-Asp-Pro-Ser-Leu-Glu-Pro-R2 (SEQ ID NO: 8);

R1-Val-Asp-Pro-Asn-Leu-Glu-Pro-R2 (SEQ ID NO: 9).

As demonstrated above, the immunogen in which Y is Lys (SEQ ID NO: 7) induces antibodies with good reactivity with the three other variants. No immunogen induced high titer antibodies with good cross-reactivity with the variant in which Y was Ser. Thus an immunogen of Epitope I in which Y was Lys (SEQ ID NO: 7) may suffice for full cross-reactivity to all four position Y variants, and may be used alone in an immunogenic composition. While this pattern of response of the peptide in which Y is Lys occurs in the majority of tests to date, it should be expected by one of skill in the art, that some differences in cross-reactivity from the results above may occur in some test samples.

Alternatively, compositions of this invention comprise two, three or all four of these amino acid sequences (SEQ ID NOS: 6-9). Alternatively, a combination of Epitope I immunogens in which Y was Lys and in which Y was Asn

(SEQ ID NO: 6) should provide somewhat better titers for Epitope I variants in which Y was Ser or Y was Asn.

Still another alternative Epitope I peptide immunogen contains at position Y an ornithine, since the ornithine side chain is similar to lysine with one less  $-CH_2-$ . This Epitope I sequence may provide even more cross-reactivity, and may be used alone or in combination with other Epitope I immunogens.

According to the formula of Epitope I above, the seven amino acid residues which form the minimum reactive Epitope I sequences, may be flanked by other amino acids, so that the entire Epitope I sequence may be between 7 and about 25 amino acids in length. As indicated in Example 1 below, the identity of the flanking amino acids is not essential to the biological function of the Epitope I immunogen. In particular additional amino acids on the N-terminus of Epitope I sequences do not affect immunogenicity. Thus, the N-terminal R1 of Epitope I may be selected from the group consisting of a free N terminal amino acid hydrogen, a lower alkyl (i.e., C1-C10 alkyl), a lower C1-C10 alkanoyl, such as an acetyl group, or a sequence of between 1 to about 5 amino acids. Preferably, R1 represents 2 amino acids.

Additional amino acids on the C-terminus of the Epitope I minimum sequence enhance antibody titer. Epitope I immunogens require at least two amino acid extensions at the C-terminus for optimal immunogenicity and are immunogenic when present within extended amino acid sequence. Thus, while the C-terminal R2 can be a simple free hydroxyl group, it can also be a C terminal amide. However, to enhance titer, R2 is preferably a sequence of between 1 to about 14 additional amino acids amidated at the carboxyl terminus. In a preferred embodiment, R2 is -Trp-Lys-His-Pro-Gly-Ser-amide (SEQ ID NO: 10).

The above-described Epitope I composition of the invention may contain a number of additional peptides or polypeptides, which contain other sequences which correspond to amino acid residues between aa 2-aa10 of SEQ ID NO: 1, but are derived from other Tat variants which do not cross-react well with antibodies to the Epitope I compositions described above. These additional peptides and polypeptides are referred to as "optional Epitope Ia immunogens". For example,

optional Epitope Ia immunogens which can be present in compositions of this invention, can contain at least one copy of at least one of the following amino acid sequences (SEQ ID NOS: 11 through 18, respectively):

- 5 R1-Gly-Pro-Arg-Leu-Glu-Pro-R2;
- R1-Ala-Pro-Arg-Leu-Glu-Pro-R2;
- R1-His-Pro-Arg-Leu-Glu-Pro-R2;
- R1-Asp-Pro-Gly-Leu-Glu-Pro-R2;
- R1-Asp-Pro-Arg-Ile-Glu-Pro-R2;
- R1-Asp-Pro-Arg-Leu-Gly-Pro-R2;
- 10 R1-Asp-Pro-Arg-Leu-Glu-Ala-R2; and
- R1-Asn-Pro-Ser-Leu-Glu-Pro-R2.

The Epitope I compositions of this invention may contain multiple copies of a single peptide, or multiple copies of different Epitope I peptides, including optionally Epitope Ia peptides, in any order, or multiple copies of at least two of these peptides. In one embodiment, at least one copy of all four amino acid sequences (SEQ ID NOS: 6-9) are present.

As described in more detail below, the Epitope I and Ia peptides or polypeptides of these compositions are produced synthetically or recombinantly. The Epitope I immunogens can be expressed as synthetic peptides coupled to a carrier protein. The Epitope I immunogens may also be expressed as multiple antigenic peptides, optionally coupled to a carrier protein. Alternatively, the Epitope I immunogens may be expressed within recombinantly produced protein, optionally co-expressed or fused in frame with a carrier protein.

Epitope I compositions demonstrate a biological activity of inducing in an immunized, immune competent mammal, i.e., a non-infected human, or an asymptomatic infected human, an active humoral immune response (i.e., antibodies) that is directed against greater than 95%, and preferably greater than 99%, of the known variants of Tat proteins of HIV-1. The end result of such treatment is an impairment of the multiplication of HIV-1 in an acute infection, thereby preventing high post-seroconversion plasma levels of HIV-1 that are associated with progression



to AIDS. Active induction of antibodies in the early asymptomatic phase of HIV infection may reduce viral multiplication, lower the plasma viral load and reduce the likelihood of progression to AIDS. The composition which contains at least one Epitope I immunogen up to all four of the SEQ ID NO: 6-9 amino acid sequences, can  
 5 elicit an immune response to about 97% of the 400 known Tat sequences of the common B subtypes of HIV-1 and with Tat proteins of all 18 non-B subtype HIV-1 that have been sequenced (courtesy of Dr. Esther Guzman, Los Alamos NIAID HIV database; GenBank database).

#### B. *Epitope II Immunogenic Compositions*

10 In another embodiment, the present invention provides a composition comprising at least one Epitope II amino acid sequence. This Epitope II sequence elicits a specific humoral immune response (for the purpose of this invention) in a mammal exposed to the Epitope II sequence *in vivo*. Epitope II defines peptides of the formula R3-Lys-X-Leu-Gly-Ile-Ser-Tyr-Gly-Arg-Lys-Lys-R4, wherein X is Gly  
 15 (70%) or Ala (30%). This sequence is highly conserved. The immunogen in which X is Gly induces antibodies cross-reactive with the sequence in which X is Ala.

The N terminal R3 may represent the hydrogen on the unmodified N terminal amino acid Lys, or R3 may be a lower alkyl, or a lower alkanoyl, such as an acetyl group, substituent on the Lys. R3 may also include a  
 20 sequence of between 1 to about 5 amino acids, optionally substituted with a lower alkyl or lower alkanoyl. The C terminal R4 may represent the free hydroxyl of the C terminal amino acid Lys, or R4 may be an amide on that C terminal amino acid. R4 may optionally be a sequence of one or up to about 5 additional amino acids, optionally substituted with an amide. The presently preferred immunogen for Epitope  
 25 II is -Lys-Gly-Leu-Gly-Ile-Ser-Tyr-Gly-Arg-Lys-Lys- (amino acids 41-51 of SEQ ID NO: 1). This would react/cross-react with greater than 96% of known HIV-1 Tat proteins.

30 Epitope II is poorly immunogenic when presented within other sequences. Thus, for optimal immunogenicity, this sequence is prepared as a synthetic peptide fused to, or coupled to, a carrier protein or as a multiple antigenic peptide,

optionally coupled to carrier protein. Alternatively, Epitope II may be expressed as the C terminal sequence of a recombinant protein, which is optionally fused in frame to a carrier protein at its amino terminal sequence. In a composition of this invention, an Epitope II peptide is preferably presented alone or in combination with one or more Epitope I peptides. Other compositions may employ one or more Epitope III or IV peptides.

### C. *Epitope III Immunogenic Compositions*

In another embodiment, the present invention provides a composition comprising at least one, and preferably two or more Epitope III amino acid sequences. These Epitope III sequences elicit a specific humoral immune response (for the purpose of this invention) in a mammal exposed to the Epitope III sequences *in vivo*. This epitope shows considerable more variation than Epitopes I and II. These Epitope III immunogenic peptides and polypeptides are derived from Tat variant protein sequences corresponding to amino acids 56-62 of SEQ ID NO: 1. Epitope III defines peptides of the formula: R5-Arg-Arg-X-Z-A-Y-Ser-R6 (SEQ ID NO: 38), wherein X may be Ala, Pro, Ser or Gln; Y may be Asp, Asn, Gly or Ser; Z may be Pro or His; and A may be Gln or Pro. The Epitope III immunogens in which X is Ala induce antibodies that cross-react with the other position X variants. Epitope III immunogens containing Asp in position Y induce antibodies that cross-react with the other position Y variants. The three most common variants for positions Z and A are -Pro-Gln- (61%), -Pro-Pro- (8%) and -His-Gln- (8%). Antibodies induced by these three immunogens do not cross-react with the others so that three immunogens would need to be used to cover these variants (77%).

According to the formula of Epitope III above, the seven amino residues which form the minimum reactive Epitope III sequences, may be flanked by other amino acids, so that the entire Epitope III sequence may be between 7 and about 15 amino acids in length. As indicated in Example 3 below, the identity of the flanking amino acids is not essential to the biological function of the Epitope III immunogen. In particular additional amino acids on the N-terminus of Epitope III sequences do not affect immunogenicity. The N terminal R5 may optionally represent the hydrogen on

the N-terminal Arg, or R5 is a lower alkyl or alkanoyl, such as an acetyl group, substituent on the N-terminal Arg. Alternatively, R5 is a sequence of between 1 to about 3 amino acids, optionally substituted with a lower alkyl or lower alkanoyl. In a preferred embodiment R5 is -Gln-Arg-, optionally modified as above, which improves the immunogenicity of the Epitope. The C terminal R6 represents either the free hydroxyl on the C terminal amino acid or an amide substituent on the C terminal amino acid, because any C-terminal extension impairs immunogenicity.

Epitope III immunogens which can be present in compositions of this invention can include at least one copy of at least one of the following preferred Epitope III amino acid sequences: R5-Gln-Arg-Arg-Arg-Ala-Pro-Gln-Asp-Ser-R6, R5-Gln-Arg-Arg-Arg-Ala-His-Gln-Asp-Ser-R6, and R5-Gln-Arg-Arg-Arg-Ala-Pro-Pro-Asp-Ser-R6, optionally modified as above (SEQ ID NOS: 20 through 22, respectively).

Still other optional immunogenic sequences which may be included in the Epitope III compositions include R5-Arg-Arg-Pro-Pro-Gln-Asp-Asn-R6, R5-Arg-Arg-Ala-Pro-Gln-Asp-Arg-R6; R5-Arg-Gly-Ala-Pro-Gln-Asp-Ser-R6; R5-Arg-Arg-Ala-Pro-Glu-Asp-Ser-R6; or R5-Arg-Arg-Ala-Ser-Gln-Asp-Ser-R6 (SEQ ID NOS: 23 through 27, respectively). As can be determined from review of the examples below, the inclusion of these Epitope III peptides in compositions of the invention can induce antibodies that react with rare Tat proteins of HIV-1 which are not cross-reactive with, or do not have a sufficiently strong cross-reactivity to, antibodies induced by the preferred Epitope III immunogens.

As described in more detail below, the Epitope III peptides or polypeptides are poorly immunogenic when presented within other sequences. Although the Epitope III sequences may be prepared recombinantly, for optimal immunogenicity, these sequences would be prepared synthetically and coupled to a carrier protein, or as multiple antigenic peptides, optionally coupled to carrier protein. Alternatively, Epitope III may be expressed as the C terminal sequence of a recombinant protein, which is optionally fused in frame to a carrier protein at its amino terminal sequence. Compositions of this invention would preferably contain three or

more different Epitope III immunogens, optionally with at least one Epitope I immunogen, and optionally with one or more Epitope II or Epitope IV immunogens.

*D. Epitope IV Immunogenic Compositions*

In another embodiment, the present invention provides a composition comprising at least one, and preferably two or more Epitope IV amino acid sequences. These Epitope IV sequences elicit a specific humoral immune response (for the purpose of this invention) in a mammal exposed to the Epitope IV sequences *in vivo*. The Epitope IV immunogenic peptides and polypeptides are derived from Tat variant protein sequences corresponding to amino acids 62-72 of SEQ ID NO: 1, including a C-terminal Pro from Exon 2 of HIV-1 Tat. Epitope IV defines peptides of the formula: R7-Ser-Gln-X-His-Gln-Y-Ser-Leu-Ser-Lys-Gln-Pro-R8 (SEQ ID NO: 39), wherein X may be Asn or Thr; and Y may be Ala or Val. The immunogen in which X is Thr induces antibodies that cross-react with the immunogen in which X is Asn. The immunogen in which Y is Val induce antibodies that do not cross-react with the peptides in which Y is Ala. However, the peptides containing Ala in position Y induce antibodies that cross-react with peptides for Epitope IV in which Y is Val. Thus the optimal Epitope IV immunogen is Ser-Gln-Thr-His-Gln-Ala-Ser-Leu-Ser Lys-Gln-Pro (SEQ ID NO: 40) and this induces antibodies reactive/cross-reactive with 64% of known HIV-1 Tat proteins.

According to the formula of Epitope IV above, the twelve amino residues which form the minimum reactive Epitope IV sequences, may be flanked by a few other amino acids, so that the entire Epitope IV sequence may be between 12 and about 18 amino acids in length. The N terminal R7 may represent the hydrogen of the N terminal amino acid, or a lower alkyl or alkanoyl, such as an acetyl group, substituent on the N terminal amino acid. Although N-terminal extension markedly inhibits immunogenicity, the R7 may also be a sequence of between 1 to about 3 amino acids, optionally substituted with a lower alkyl or lower alkanoyl. The C terminal R8 may represent the free hydroxyl on the C terminal amino acid, or an amide substituent on the C terminal amino acid, or R8 may be a sequence of one or up to about 3 additional amino acids, optionally substituted with an amide. Additionally,

the C-terminal Pro, which is an important component of the epitope, is encoded by Exon 2 of Tat. Thus antibodies to Epitope IV would be poorly reactive with non-spliced Tat Exon 1 protein.

5 This Epitope IV sequence is poorly immunogenic when presented within other sequences. Thus, for optimal immunogenicity, this sequence would be prepared as a synthetic peptide coupled to carrier protein or as a multiple antigenic peptide, optionally coupled to carrier protein. Compositions of this invention would preferably contain two or more different Epitope IV immunogens, optionally with at least one Epitope I immunogen, and optionally with one or more Epitope II or  
10 Epitope III immunogens.

*E. Compositions containing multiple Epitopes*

While the amino acid sequences of Epitope I, II, III and IV and optional immunogens identified herein were obtained by rigorous analysis of over 400 known Tat sequences of HIV-1, it should be understood by one of skill in the art that  
15 similar compositions may be obtained, following the teachings of this invention, from the study of further Tat proteins, the nucleic acid sequences encoding them, and fragments thereof from newly isolated Tat proteins of HIV-1 subtype B, or from Tat proteins of the other subtypes, or from other HIV strains.

Thus, the compositions of this invention, i.e., the  
20 peptide/polypeptides containing the above-identified amino acid sequences, when provided to a human subject, are useful in the immunologic interdiction of extracellular Tat proteins of most HIV-1 strains. These compositions function to critically reduce explosive multiplication of the virus and permit effective immune control of the virus.

The immunogens for each Epitope are preferably designed to  
25 induce antibodies reactive with the highest proportion of naturally occurring variants of each epitope. For an epitope such as Epitope I, multiple copies of an immunogen could be incorporated in a synthetic or recombinant immunogen to enhance the immunogenicity and produce higher titer antibodies. Furthermore, immunogens for two or more epitopes could be combined to extend coverage, since variations in  
30 sequence of each epitope occur independently. For example, combining an Epitope I

immunogen(s) (95%) with an Epitope II immunogen (96%) would result in antibodies in immunologically responsive subjects reactive with 99.8% of known HIV-1 Tat proteins. Thus, as one example, a composition of this invention contains one Epitope I (underlined)-Epitope II (double-underlined) fused peptide immunogen such as Cys-  
 5 Glu-Pro-Val-Asp-Pro-Lys-Leu-Glu-Pro-Trp-Lys-Glu-Leu-Gly-Ile-Ser-Tyr-Gly-Arg-Lys-Lys-amide (SEQ ID NO: 67), coupled to carrier protein attached to Epitope I, or the same peptide (less the N-terminal Cys for coupling), synthesized as a multiple antigenic peptide, optionally coupled to a carrier protein. Alternatively, mixtures of two or more immunogens could be used as follows.

10 The Epitope I immunogens, with or without any Epitope II, III or IV or other optional immunogens, may be prepared and used in immunogenic compositions in a variety of forms, for example, chemically synthesized or as recombinant peptides, polypeptides, proteins, fusion proteins or fused peptides.

1. Synthetic Peptide/Protein Coupled to a Carrier

15 As one embodiment, a composition of the present invention may be a synthetic peptide, containing single or multiple copies of the same or different Epitope I immunogen amino acid sequences and/or Epitope II/III/IV immunogenic amino acid sequences, and optionally amino acid sequences of the optional immunogens, coupled to a selected carrier protein. In this embodiment of a  
 20 composition of this invention, multiple above-described Epitope I amino acid sequences with or without flanking sequences, may be combined sequentially in a polypeptide and coupled to the same carrier. Alternatively, the Epitope I, II, III, or IV immunogens, may be coupled individually as peptides to the same or different carrier proteins, and the resulting immunogen-carrier constructs mixed together to form a  
 25 single composition.

For this embodiment, the carrier protein is desirably a protein or other molecule which can enhance the immunogenicity of the selected immunogen. Such a carrier may be a larger molecule which has an adjuvanting effect. Exemplary conventional protein carriers include, without limitation, *E. coli* DnaK  
 30 protein, galactokinase (galK, which catalyzes the first step of galactose metabolism in

bacteria), ubiquitin,  $\alpha$ -mating factor,  $\beta$ -galactosidase, and influenza NS-1 protein. Toxoids (i.e., the sequence which encodes the naturally occurring toxin, with sufficient modifications to eliminate its toxic activity) such as diphtheria toxoid and tetanus toxoid may also be employed as carriers. Similarly a variety of bacterial heat shock proteins, e.g., mycobacterial hsp-70 may be used. Glutathione reductase (GST) is another useful carrier. One of skill in the art can readily select an appropriate carrier.

In particularly desirable immunogen-carrier protein construct, one or more epitope immunogen and optional immunogen peptides/polypeptides may be covalently linked to a mycobacterial *E. coli* heat shock protein 70 (hsp70) (K. Suzue et al, J. Immunol., 156:873 (1996)). In another desirable embodiment, the composition is formed by covalently linking the immunogen-containing peptide or polypeptide sequences to diphtheria toxoid.

## 2. Multiple Antigenic Peptide

In yet another embodiment, the peptides or polypeptide epitope immunogens and any selected optional immunogens may be in the form of a multiple antigenic peptide ("MAP", also referred to as an octameric lysine core peptide) construct. Such a construct may be designed employing the MAP system described by Tam, Proc. Natl. Acad. Sci. USA, 85:5409-5413 (1988). This system makes use of a core matrix of lysine residues onto which multiple copies of the same Epitope I or optional immunogens of the invention are synthesized as described (D. Posnett et al., J. Biol. Chem., 263(4):1719-1725 (1988); J. Tam, "Chemically Defined Synthetic Immunogens and Vaccines by the Multiple Antigen Peptide Approach", Vaccine Research and Developments, Vol. 1, ed. W. Koff and H. Six, pp. 51-87 (Marcel Deblau, Inc., New York 1992)). Each MAP contains multiple copies of only one peptide. Therefore, e.g., an epitope composition of this invention can include a MAP in which the peptide or polypeptide epitope immunogen attached to the lysine core contains one or sequential repeats of the four amino acid sequences (SEQ ID NOS: 6-9) identified above. Multiple different MAPs may be employed to obtain any desired combination of Epitope I, II, III or IV sequences. Preferably these MAP constructs are associated with other T cell stimulatory sequences, or as pharmaceutical

compositions, administered in conjunction with T cell stimulatory agents, such as known adjuvants.

### 3. Spacers

In either of the above compositions, e.g., as peptide/polypeptide-carrier constructs or MAPs, each peptide/polypeptide immunogen, or each amino acid sequence in the immunogen, may be optionally separated by optional amino acid sequences called "spacers". Spacers are sequences of between 1 to about 4 amino acids which are interposed between two sequences to permit linkage therebetween without adversely effecting the three dimensional structure of the immunogen. Spacers may also contain restriction endonuclease cleavage sites to enable separation of the sequences, where desired. Suitable spacers or linkers are known and may be readily designed and selected by one of skill in the art. Preferred spacers are sequences containing Gly and/or Ser amino acids.

### F. *Nucleic Acid Compositions of the Invention, including a Synthetic Gene*

Other embodiments of this invention include nucleic acid sequences, which encode the above-described peptide/polypeptide compositions, including the peptide and polypeptide immunogens of the compositions described above, including those peptides and polypeptides fused to carrier proteins. The nucleic acid sequences may also include sequences encoding the carrier proteins.

Thus, one preferred embodiment of the invention is a "synthetic gene" which encodes sequentially for one or more Epitope I immunogenic peptides/polypeptide. The synthetic gene preferably encodes two, three or all four Epitope I amino acid sequences (SEQ ID NOS: 6 through 9, respectively):

R1-Val-Asp-Pro-Arg-Leu-Glu-Pro-R2;  
R1-Val-Asp-Pro-Lys-Leu-Glu-Pro-R2;  
R1-Val-Asp-Pro-Ser-Leu-Glu-Pro-R2; and  
R1-Val-Asp-Pro-Asn-Leu-Glu-Pro-R2.

The synthetic gene can also encode any selection of the optional immunogens identified above, and may include an Epitope II or III immunogen provided that the



Epitope II or III peptide is fused to the C terminus of the Epitope I sequence and not further modified on its own C terminus. The synthetic gene may encode multiple copies of the same amino acid sequence, copies of multiple different immunogens or amino acid sequences, or multiple copies of multiple different immunogens or amino acid sequences. The synthetic gene may encode the selected amino acid sequences in an open reading frame with, or fused to, a nucleic acid sequence encoding a carrier protein. A further characteristic of the synthetic gene may be that it encodes a spacer between each sequence encoding an immunogen and/or between the sequence encoding an immunogen and the sequence encoding the carrier protein.

The synthetic gene of the present invention may also be part of a synthetic or recombinant molecule. The synthetic molecule may be a nucleic acid construct, such as a vector or plasmid which contains the synthetic gene encoding the protein, peptide, polypeptide, fusion protein or fusion peptide under the operative control of nucleic acid sequences encoding regulatory elements such as promoters, termination signals, and the like. Such synthetic molecules may be used to produce the polypeptide/peptide immunogen compositions recombinantly.

The synthetic gene or synthetic molecules can be prepared by the use of chemical synthesis methods or preferably, by recombinant techniques. For example, the synthetic gene or molecules may contain certain preference codons for the species of the indicated host cell.

The synthetic gene or molecules, preferably in the form of DNA, may be used in a variety of ways. For example, these synthetic nucleic acid sequences may be employed to express the peptide/polypeptides of the invention *in vitro* in a host cell culture. The expressed immunogens, after suitable purification, may then be incorporated into a pharmaceutical reagent or vaccine.

Alternatively, the synthetic gene or synthetic molecule of this invention may be administered directly into a mammalian, preferably human subject, as so-called 'naked DNA' to express the protein/peptide immunogen *in vivo* in a patient. See, e.g., J. Cohen, Science, 259:1691-1692 (March 19, 1993); E. Fynan et al., Proc. Natl. Acad. Sci., USA, 90:11478-11482 (Dec. 1993); and J. A. Wolff et al.,

Biotechniques, 11:474-485 (1991), all incorporated by reference herein. The synthetic molecule, e.g., a vector or plasmid, may be used for direct injection into the mammalian host. This results in expression of the protein by host cells and subsequent presentation to the immune system to induce antibody formation *in vivo*.

5                   G.     *Microorganisms That Express The Synthetic Gene*

In still another aspect of the present invention, the synthetic genes or molecules of this invention may be incorporated into a non-pathogenic microorganism. The resulting microorganism, when administered to a mammalian host expresses and multiplies the expressed compositions of this invention *in vivo* to induce specific antibody formation. For example, non-pathogenic recombinant viruses or commensal bacterium which carry the compositions or synthetic genes of this invention and are useful for administration to a mammalian patient may be prepared by use of conventional methodology and selected from among known non-pathogenic microorganisms.

10                   Among commensal bacterium which may be useful for exogenous delivery of the synthetic molecule to the patient, and/or for carrying the synthetic gene into the patient *in vivo*, include, for example, various strains of *Streptococcus*, e.g., *S. gordonii*, or *E. coli*, *Bacillus*, *Streptomyces*, and *Saccharomyces*.

15                   Suitable non-pathogenic viruses which may be engineered to carry the synthetic gene into the cells of the host include poxviruses, such as vaccinia, adenovirus, canarypox, retroviruses and the like. A number of such non-pathogenic viruses are commonly used for human gene therapy, and as carrier for other vaccine agents, and are known and selectable by one of skill in the art.

20                   H.     *Preparation or Manufacture of Compositions of the Invention*

The compositions of the invention, and the individual polypeptides/peptides containing the Epitope I, II, III or Epitope IV or optional immunogens of this invention, the synthetic genes, and synthetic molecules of the invention, may be prepared conventionally by resort to known chemical synthesis techniques, such as described by Merrifield, J. Amer. Chem. Soc., 85:2149-2154

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(1963). Alternatively, the compositions of this invention may be prepared by known recombinant DNA techniques by cloning and expressing within a host microorganism or cell a DNA fragment carrying a sequence encoding a peptide/polypeptide containing an Epitope I and/or optional immunogen and optional carrier protein. Coding sequences for the Epitope I and optional immunogens can be prepared synthetically (W. P. C. Stemmer et al, Gene, 164:49 (1995) or can be derived from viral RNA by known techniques, or from available cDNA-containing plasmids.

Combinations of these techniques may be used, such as for production of the synthetic gene, which may require assembly of sequential immunogens by conventional molecular biology techniques, and site-directed mutagenesis to provide desired sequences of immunogens. The product of the synthetic gene is then produced recombinantly. All of these manipulations may be performed by conventional methodology.

Systems for cloning and expressing the peptide/polypeptide compositions of this invention using the synthetic genes or molecules, include various microorganisms and cells which are well known in recombinant technology. These include, for example, various strains of *E. coli*, *Bacillus*, *Streptomyces*, and *Saccharomyces*, as well as mammalian, yeast and insect cells. Suitable vectors therefor are known and available from private and public laboratories and depositories and from commercial vendors. Currently, the most preferred host is a mammalian cell such as Chinese Hamster ovary cells (CHO) or COS-1 cells. These hosts may be used in connection with poxvirus vectors, such as vaccinia or swinepox. The selection of other suitable host cells and methods for transformation, culture, amplification, screening and product production and purification can be performed by one of skill in the art by reference to known techniques. See, e.g., Gething and Sambrook, Nature, 293:620-625 (1981).

Another preferred system includes the baculovirus expression system and vectors.

When produced by conventional recombinant means, the compositions of this invention, i.e., the polypeptide/peptides containing the indicated copies of the Epitope I immunogens and optional immunogens may be isolated either from the cellular contents by conventional lysis techniques or from cell medium by conventional methods, such as chromatography. See, e.g., Sambrook et al., Molecular Cloning. A Laboratory Manual., 2d Edit., Cold Spring Harbor Laboratory, New York (1989).

Suitable plasmid and viral vectors used either for production of the peptide/polypeptide components as DNA vaccines are well known to those of skill in the art and are not a limitation of the present invention. See, Sambrook et al., cited above and the references above to production of the protein. See, also International Patent Publication No. WO94/01139, published January 20, 1994.

Briefly, the DNA encoding the selected peptide/polypeptide is inserted into a vector or plasmid which contains other optional flanking sequences, a promoter, an mRNA leader sequence, an initiation site and other regulatory sequences capable of directing the multiplication and expression of that sequence *in vivo* or *in vitro*. These vectors permit infection of patient's cells and expression of the synthetic gene sequence *in vivo* or expression of it as a protein/peptide or fusion protein/peptide *in vitro*.

The resulting composition may be formulated into a Epitope I composition with any number of optional immunogens and screened for efficacy by *in vivo* assays. Such assays employ immunization of an animal, e.g., a rabbit or a simian, with the composition, and evaluation of titers of antibody to the Tat proteins of HIV-1 or to synthetic detector peptides corresponding to variant Tat sequences (as shown in the examples below).

#### *I. Antibody Compositions of the Invention*

An isolated mammalian antibody composition which is directed against a peptide or polypeptide of the invention, as described above, is also an aspect of this invention. Such polyclonal antibody compositions are produced by immunizing a mammal with a peptide/polypeptide composition containing an assortment of Epitope

I, II, III, and/or IV immunogens and optional immunogens, as described above. Suitable mammals include primates, such as monkeys; smaller laboratory animals, such as rabbits and mice, as well as larger animals, such as horse, sheep, and cows. Such antibodies may also be produced in transgenic animals. However, a desirable host for raising polyclonal antibodies to a composition of this invention includes humans.

The polyclonal antibodies raised in the mammal exposed to the composition are isolated and purified from the plasma or serum of the immunized mammal by conventional techniques. Conventional harvesting techniques can include plasmapheresis, among others.

Such polyclonal antibody compositions may themselves be employed as pharmaceutical compositions of this invention. Alternatively, other forms of antibodies may be developed using conventional techniques, including monoclonal antibodies, chimeric antibodies, humanized antibodies and fully human antibodies. See, e.g., Harlow *et al.*, Antibodies A Laboratory Manual, Cold Spring Harbor Laboratory, (1988); Queen *et al.*, Proc. Nat'l. Acad. Sci. USA, 86:10029-10032 (1989); Hodgson *et al.*, Bio/Technology, 9:421 (1991); International PCT Application PCT/GB91/01554, Publication No. WO92/04381 and International PCT Application PCT/GB93/00725, Publication No. WO93/20210). Other anti-Tat antibodies may be developed by screening hybridomas or combinatorial libraries, or antibody phage displays (W. D. Huse *et al.*, Science, 246:1275-1281 (1988)) using the polyclonal or monoclonal antibodies produced according to this invention and the amino acid sequences of the Epitope I, II, III, IV or optional immunogens.

These antibody compositions bind to greater than 95%, and preferably greater than 99% of known Tat protein variants of HIV-1, and prevent the Tat proteins from supporting further HIV-1 multiplication. Thus, these antibodies are useful in pharmaceutical methods and formulations described below.

#### *J. Pharmaceutical Compositions of the Invention*

As another aspect of this invention, a pharmaceutical composition useful for inducing antibodies that react with greater than 95%, preferably greater than 99%, of known HIV-1 Tat proteins and impair the multiplication of HIV-

I can comprise as its active agents, one or more of the peptides or polypeptides of Epitope I, II, III, or IV. Several desirable compositions include the following above-described components:

(a) a peptide/polypeptide immunogen which contains at least one, and preferably all four of the Epitope I amino acid sequences SEQ ID NOS: 6-9;

(b) a peptide/polypeptide immunogen which contains at least one of the Epitope II amino acid sequences;

(c) a peptide/polypeptide immunogen which contains at least one, and preferably three Epitope III amino acid sequences;

(d) a peptide/polypeptide immunogen which contains at least one Epitope IV amino acid sequence;

(e) a synthetic gene encoding one or more of Epitope I, Epitope II, Epitope III, or Epitope IV sequences as described above;

(f) a synthetic molecule described above;

(g) a recombinant virus carrying the synthetic gene or molecule; and

(h) a commensal bacterial carrying the synthetic gene or molecule.

The selected active component(s) is present in a pharmaceutically acceptable carrier, and the composition may contain additional ingredients. Pharmaceutical formulations containing the compositions of this invention may contain other active agents, such as T cell stimulatory agents for the MAPs, adjuvants and immunostimulatory cytokines, such as IL-12 and other well-known cytokines, for the protein/peptide compositions. All of these pharmaceutical compositions can operate to lower the viral levels of a mammal.

As pharmaceutical compositions, these compositions comprising Epitope I and/or II, and/or III, and/or IV amino acid sequences with optional immunogenic amino acid sequences are admixed with a pharmaceutically acceptable vehicle suitable for administration as a protein composition for prophylaxis or

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treatment of virus infections. These proteins may be combined in a single pharmaceutical preparation for administration. Suitable pharmaceutically acceptable carriers for use in an immunogenic proteinaceous composition of the invention are well known to those of skill in the art. Such carriers include, for example, saline, buffered saline, a selected adjuvant, such as aqueous suspensions of aluminum and magnesium hydroxides, liposomes, oil in water emulsions and others. Suitable adjuvants may also be employed in the protein-containing compositions of this invention. The present invention is not limited by the selection of the carrier or adjuvant.

Suitable vehicles for direct DNA, plasmid nucleic acid, or recombinant vector administration include, without limitation, saline, or sucrose, protamine, polybrene, polylysine, polycations, proteins,  $\text{CaPO}_4$  or spermidine. See e.g., International Patent Publication No. WO94/01139 and the references cited above.

The peptide/polypeptide compositions and synthetic genes or molecules *in vivo* are capable of eliciting in an immunized host mammal, e.g., a human, an immune response capable of interdicting greater than about 95 to about 99 % of known extracellular Tat protein variants from HIV-1 and thereby lowering the viral levels.

Yet another pharmaceutical composition useful for impairing the multiplication of HIV-1 comprises an antibody composition as described in detail above. In a pharmaceutical composition, the antibodies may be carried in a saline solution or other suitable carrier. The antibody compositions are capable of providing an immediate, exogenously provided interdiction of Tat.

The preparation of these pharmaceutically acceptable compositions, from the above-described components, having appropriate pH isotonicity, stability and other conventional characteristics is within the skill of the art.

*K. Method of the Invention - Impairing Multiplication of HIV-1*

According to the present invention, a method for reducing the viral levels of HIV-1 involves exposing a human to the Tat antibody-inducing pharmaceutical compositions described above, actively inducing antibodies that react with greater than 95%, preferably greater than 99%, of known HIV-1 Tat proteins,

and impairing the multiplication of the virus *in vivo*. This method is appropriate for an HIV-1 infected subject with a competent immune system, or an uninfected or recently infected subject. The method induces antibodies which react with HIV-1 Tat proteins, which antibodies reduce viral multiplication during any initial acute infection with HIV-1 and minimize chronic viremia leading to AIDS. This method also lowers chronic viral multiplication in infected subjects, again minimizing progression to AIDS.

In one embodiment, the pharmaceutical compositions may be therapeutically administered to an HIV-1 infected human with a competent immune system for treatment or control of viral infection. Such an infected human may be asymptomatic. In a similar embodiment, the pharmaceutical compositions may be administered to an uninfected human for prophylaxis.

In these two instances, the pharmaceutical compositions preferably contain the peptide/polypeptide compositions, the synthetic genes or molecules, the recombinant virus or the commensal recombinant bacterium. Each of these active components of the pharmaceutical composition actively induces in the exposed human the formation of anti-Tat antibodies which block the transfer of Tat from infected cells to other infected or uninfected cells. This action reduces the multiplicity of infection and blocks the burst of HIV-1 viral expansion, and thus lowers viral levels. In already infected patients, this method of reduction of viral levels can reduce chronic viremia and progression to AIDS. In uninfected humans, this administration of the compositions of the invention can reduce acute infection and thus minimize chronic viremia leading to progression to AIDS.

Yet another aspect of the invention is a method for reducing the viral levels of HIV-1 by administering to a human, who is incapable of mounting an effective or rapid immune response to infection with HIV-1, a pharmaceutical composition containing the antibody compositions described above. The method can involve chronically administering the composition. Among such patients suitable for treatment with this method are HIV-1 infected patients who are immunocompromised by disease and unable to mount a strong immune response. In later stages of HIV infection, the likelihood of generating effective titers of antibodies is less, due to the



immune impairment associated with the disease. Also among such patients are HIV-1 infected pregnant women, neonates of infected mothers, and unimmunized patients with putative exposure (e.g., a human who has been inadvertently "stuck" with a needle used by an HIV-1 infected human).

5 For such patients, the method of the invention preferably employs as the pharmaceutical composition the antibody composition of the invention, which is a polyclonal antibody composition prepared in other mammals, preferably normal humans. Alternatively, the other forms of antibody described above may be employed. These antibody compositions are administered as passive immunotherapy  
10 to inhibit viral multiplication and lower the viral load. The exogenous antibodies which react with greater than 95%, preferably greater than 99%, of known Tat proteins from HIV-1 provide in the patient an immediate interdiction of the transfer of Tat from virally infected cells to other infected or uninfected cells. According to this method, the patient may be chronically treated with the antibody composition for a long  
15 treatment regimen.

In each of the above-described methods, these compositions of the present invention are administered by an appropriate route, e.g., by the subcutaneous, oral, intravenous, intraperitoneal, intramuscular, nasal, or inhalation routes. The presently preferred route of administration is intramuscular for the  
20 immunizing (active induction) compositions and intravenous or intramuscular for the antibody (passive therapy) compositions. The recombinant viral vectors or naked DNA is preferably administered i.m.; however, other certain recombinant viral vectors and/or live commensal bacteria may be delivered orally.

The amount of the protein, peptide or nucleic acid sequences of the invention present in each vaccine dose is selected with regard to consideration of  
25 the patient's age, weight, sex, general physical condition and the like. The amount of active component required to induce an immune response, preferably a protective response, or produce an exogenous effect in the patient without significant adverse side effects varies depending upon the pharmaceutical composition employed and the  
30 optional presence of an adjuvant (for the protein-containing compositions).

Generally, for the compositions containing protein/peptide, fusion protein, MAP or coupled protein, or antibody composition, each dose will comprise between about 50  $\mu$ g to about 2 mg of the peptide/polypeptide immunogens per mL of a sterile solution. A more preferred dosage may be about 500  $\mu$ g of immunogen. Other dosage ranges may also be contemplated by one of skill in the art. Initial doses may be optionally followed by repeated boosts, where desirable

The antibody compositions of the present invention can be employed in chronic treatments for subjects at risk of acute infection due to needle sticks or maternal infection. A dosage frequency for such "acute" infections may range from daily dosages to once or twice a week i.v. or i.m., for a duration of about 6 weeks. The antibody compositions of the present invention can also be employed in chronic treatments for infected patients, or patients with advanced HIV. In infected patients, the frequency of chronic administration may range from daily dosages to once or twice a week i.v. or i.m., and may depend upon the half-life of the immunogen (e.g., about 7-21 days). However, the duration of chronic treatment for such infected patients is anticipated to be an indefinite, but prolonged period.

Alternatively, compositions of this invention may be designed for direct administration of synthetic genes or molecules of this invention as "naked DNA". As with the protein immunogenic compositions, the amounts of components in the DNA and vector compositions and the mode of administration, e.g., injection or intranasal, may be selected and adjusted by one of skill in the art. Generally, each dose will comprise between about 50  $\mu$ g to about 1 mg of immunogen-encoding DNA per mL of a sterile solution.

For recombinant viruses containing the synthetic genes or molecules, the doses may range from about 20 to about 50 ml of saline solution containing concentrations of from about  $1 \times 10^7$  to  $1 \times 10^{10}$  pfu/ml recombinant virus of the present invention. A preferred human dosage is about 20 ml saline solution at the above concentrations. However, it is understood that one of skill in the art may alter such dosages depending upon the identity of the recombinant virus and the make-up of the immunogen that it is delivering to the host.

The amounts of the commensal bacteria carrying the synthetic gene or molecules to be delivered to the patient will generally range between about  $1 \times 10^3$  to about  $1 \times 10^{12}$  cells/kg. These dosages, will of course, be altered by one of skill in the art depending upon the bacterium being used and the particular composition containing Epitope I, or Epitope II or Epitope III or Epitope IV and optional immunogens being delivered by the live bacterium.

Thus, the compositions of this invention are designed to retard or minimize infection by the selected virus of an uninfected mammal, e.g., human. Such compositions thus have utility as vaccines. Anti-Tat protein antibodies are not reactive with the HIV-1 proteins used in diagnostic assays to detect seroconversion after infection. Thus, subjects treated with the compositions of this invention would not be stigmatized with false-positive tests for HIV-1 infection, and it would remain possible to detect seroconversion if treated subjects did become infected with HIV-1.

Providing a mammal with the compositions of this invention, whether as a protein/peptide-containing composition or by administration of a novel nucleic acid sequence encoding the immunogen, affords a radically different strategy for AIDS vaccination because it permits the lowering of viral levels by biological interdiction of greater than about 95%, and preferably greater than about 99%, of known Tat protein variants of HIV-1, lowering multiplication of HIV-1.

The use of the Tat immunogen-containing compositions has a particularly desirable advantage in contrast to other treatments and prophylactic methods employed against such viruses. Because interdiction of the Tat protein extracellularly inhibits the multiplication of all HIV quasi-species or strains indiscriminately, it does not create a selective pressure on the parent virus itself for selection of mutant virus variants. Thus, blocking the uptake of Tat protein by the patient's cells not only reduces the level of viremia, but does so in a manner that precludes the selection of "escape variants".

Additionally, the invention comprises a method of actively treating asymptomatic HIV-1 infected subjects with viremia, since during the course of the disease, extracellular Tat protein likely contributes to the persistent infection and

immune abnormalities that are present at this stage of HIV-1 infection. Interdiction of extracellular Tat protein by antibodies induced by immunization according to this invention can reduce viremia with more effective immune control, and result in delay or prevention of progression to AIDS.

5                   The mechanism of the present invention as described above is useful in impeding the course of viral infection and producing desirable clinical results. More specifically, the compositions of this invention are capable of reducing viremia in patients already infected with the virus by blocking further uptake of the Tat protein by uninfected cells. The compositions of the present invention, used either alone or in  
10                   conjunction with other therapeutic regimens for HIV infected patients, are anticipated to assist in the reduction of viremia and prevention of clinical deterioration.

                  For such therapeutic uses, the formulations and modes of administration are substantially identical to those described specifically above and may be administered concurrently or simultaneously with other conventional therapeutics  
15                   for the specific viral infection. For therapeutic use or prophylactic use, repeated dosages of the immunizing compositions may be desirable, such as a yearly booster or a booster at other intervals.

*L.       Diagnostic Kits of this Invention*

                  The peptides and polypeptides described above can also be  
20                   employed as reagents of a kit useful for the measurement and detection of titers and specificities of antibodies induced by vaccination with the compositions described above. The kit of the invention can include one or more peptides of Epitopes I through IV. In one embodiment, each peptide has on its N terminus the protein biotin and a spacer, e.g., -Ser-Gly-Ser-Gly- (SEQ ID NO: 30). Alternatively, the peptide may  
25                   have on its C terminus a spacer, e.g., -Gly-Ser-Gly-Ser- (SEQ ID NO: 90), and the protein biocytin. These embodiments enable the peptides to be bound to an avidin-coated solid support, e.g., a plate or beads. Of course, other binding agents known to those of skill in the diagnostic assay art may also be employed for the same purposes. Also provided in the kit are, labeled reagents which detect the binding of antibody to  
30                   the immobilized Epitope peptides, such as a goat anti-human immunoglobulin or the

like. The label on the reagent may be selected from the many known diagnostic labels, such as radioactive compounds, fluorescent compounds and proteins, colorimetric enzymes, etc. The kit thus also contains miscellaneous reagents and apparatus for reading labels, e.g., certain substrates that interact with an enzymatic label to produce a color signal, etc., apparatus for taking blood samples, as well as appropriate vials and other diagnostic assay components. One of skill in the art may also readily select other conventional diagnostic components for this kit.

Such kits and reagents may be employed in a method for detecting the titers and reactivity patterns of antibodies in subjects vaccinated with the compositions of this invention. A method for determining the presence and or titer of antibodies induced by immunization to a Tat immunogen includes the steps of contacting a biological sample from an immunized subject, e.g., a body fluid, preferably blood, serum or plasma, but also possibly urine, saliva and other fluids or tissue, with one or more of the binding sequences of Epitope I, II, III or IV, preferably immobilized on a solid support, such as a plate or beads. The Epitope I, II, III or IV binding sequences employed in this method may be the minimal binding regions, unmodified. Therefore, such sequences include -Val-Asp-Pro-Y-Leu-Glu-Pro- (SEQ ID NO: 86) or -Glu-Pro-Val-Asp-Pro-Y-Leu-Glu-Pro- (SEQ ID NO: 124), wherein Y is selected from the group consisting of Arg, Lys, Ser and Asn; and/or -Lys-X-Leu-Gly-Ile-Ser-Tyr-Gly-Arg-Lys-Lys- (SEQ ID NO: 87), wherein X is selected from the group consisting of Gly or Ala; and/or -Arg-Arg-X-Z-A-Y-Ser- (SEQ ID NO: 88), wherein X is selected from the group consisting of Ala, Pro, Ser and Gln; wherein Y is selected from the group consisting of Asp, Asn, Gly and Ser; wherein Z is selected from the group consisting of Pro and His; wherein A is selected from the group consisting of Gln and Pro; and/or -Ser-Gln-X-His-Gln-Y-Ser-Leu-Ser-Lys-Gln-Pro- (SEQ ID NO: 89), wherein X is selected from the group consisting of Asn and Thr; wherein Y is selected from the group consisting of Ala and Val.

Once the biological sample is exposed to the immobilized peptides for a sufficient time, the support is washed to eliminate any material from the biological sample which is not bound to the peptides. Such washing steps are conventional in

diagnostic assays, and performed with saline. If antibodies to Epitopes I, or II, or III, or IV, or a combination thereof, were induced in the subject by the above-described treatment, the immobilized peptides have been bound with an antibody from the biological sample. Thereafter, a labeled reagent is added to the material on the support to detect the binding between the peptides on the solid support and antibody in said biological sample. Preferably, such a reagent is an anti-human immunoglobulin, such as goat anti-human immunoglobulin. The label is selected from among a wide array of conventionally employed diagnostic labels, as discussed above. In one embodiment, the label can be a colorimetric enzyme, which upon contact with a substrate produces a detectable color signal. The presence and/or intensity of the color provides evidence of the induction of antibody in the treated subject. This assay may be employed to determine the efficacy of the immunization, as well as to monitor immune status of a patient.

Again, the selection of particular assay steps, as well as a variety of detectable label systems, is well within the skill of the art. Such selection is routine and does not limit the present invention.

*M. Advantages of the Invention*

One of the advantages of the compositions of this invention is the small number of immunogens required for inclusion into a composition of this invention to cross-react with greater than 95 to greater than 99% of known Tat protein variants of HIV-1 of the common B subtype. As mentioned above, an immunogen of Epitope I in which Y was Lys (SEQ ID NO: 7) could suffice for full cross-reactivity to all four position Y variants, and could be used alone in an immunogenic composition. Alternatively, as illustrated in the examples below, the Epitope I immunogenic composition containing all four Epitope I amino acid sequences cross-reacts with 387 of 399 Tat proteins of HIV-1 of the common B subtype, as well as with all 18 Tat protein sequences from less frequent non-B subtypes of HIV-1. Thus, a single composition may be usefully employed in protecting against or treating infection, caused by the vast majority of HIV-1 strains that can be encountered.

Further, having identified the precise epitopes on Tat against which binding is desired (i.e., AA2-10, AA41-51, or AA56-62 of SEQ ID NO: 1) new desirable Tat peptide immunogens from newly occurring HIV-1 strains or newly discovered strains may be easily identified using the methods described herein, and included in the compositions. This flexibility enables the compositions of this invention to be useful prophylactically against any new strain or strains of HIV-1 identified in the future. In view of the teachings herein, one of skill in the art is expected to be readily able to incorporate new combinations of Tat immunogens (and the nucleic acid constructs encoding them) into the compositions.

For example, the use of conventional techniques such as PCR and high density oligonucleotide arrays (M. J. Kozal et al, Nature Med., 2:753 (1996)) enables one of skill in the art to obtain the amino acid sequences of a large array of HIV-1 Tat proteins representing variants of clinical isolates of HIV-1 strains and subtypes. Using such techniques permits determination of other variants of the HIV-1 B subtype as well as other subtypes in undeveloped countries, which have not been so intensively studied to date. The determination of new Tat sequences will enable ready inclusion of the corresponding peptides as immunogens into compositions of this invention, allowing the induction of an antibody response against other rare Tat proteins of HIV-1.

Cross-reactivity studies with antibodies raised to synthetic peptides corresponding to each Tat variant can be utilized to eliminate the need for immunizing with Tat variants in which the sequence changes are immunologically silent, in that these peptides are strongly bound by antibodies to the consensus sequence or other variants.

The following examples illustrate preferred methods for preparing the compositions of the invention and utilizing these compositions to induce antibodies to Tat proteins of the virus in an immunized host. These examples are illustrative only and do not limit the scope of the invention.

EXAMPLE 1 - IMMUNOLOGICAL STUDIES ON MINIMAL TAT PROTEIN  
AMINO ACID SEQUENCES NECESSARY FOR BINDING TO ANTIBODY FOR  
EPITOPE I IN HIV-1 TAT PROTEIN

A peptide corresponding to amino acids 4-16 of SEQ ID NO: 1  
illustrated in Fig. 1 was synthesized as described below. This sequence is among the  
most frequent sequence representation at these positions in 31 Tat protein sequences  
of the common B subtype reported in the NIAID HIV database. This sequence was  
chosen as a putative immunogen, named Epitope I.

*A. Peptide synthesis - Immunizing peptides*

The amino acid sequence of this immunogen  
-Val-Asp-Pro-Arg-Leu-Glu-Pro-Trp-Lys-His-Pro-Gly-Ser- (SEQ ID NO: 28) was  
synthesized by solid phase methodology on polypropylene pegs according to the  
methods of H. M. Geysen *et al.*, J. Immunol. Meth., 102:259 (1987), with an N-  
terminal cysteinyl being incorporated to facilitate coupling to a carrier protein. The N-  
terminus was left as a free amine and the C-terminus was amidated in the immunizing  
peptides for most of the experiments for which data is reported in Table 2 below.  
Immunizing peptides were generally purified to greater than 95% purity by reverse  
phase HPLC, and purity was further confirmed by mass spectrometry (MS).

Immunizing peptides were covalently coupled to diphtheria  
toxoid (DT) carrier protein via the cysteinyl side chain by the method of A. C. J. Lee *et al.*,  
Molec. Immunol., 17:749 (1980), using a ratio of 6-8 moles peptide per mole of  
diphtheria toxoid.

*B. Peptide synthesis - Detector peptides*

A peptide corresponding to the amino acid sequence of the  
immunogen peptide was synthesized by the method of Geysen, cited above, for use in  
ELISA assays for detection of reactivity and cross-reactivity. Additional peptides with  
N- and C-terminal truncations were also synthesized.

For most of the experiments reported below in Tables 2 and 3,  
detector peptides had an N-terminal -Ser-Gly-Ser-Gly- (SEQ ID NO: 30) added, with  
biotinylation of the new N-terminus, and the C-terminal remained a free acid. The C-



terminal detecting peptides for some of these experiments had been inadvertently synthesized with an amidated C-terminus, which may have led to a spuriously high binding for (SEQ ID NO: 32) -Asp-Pro-Arg-Leu-Glu-Pro-Trp-Lys-His-Pro-Gly-Ser- reported in Tables 2 and 3 below. Therefore, several peptides were resynthesized with appropriate C-terminal groups and the pertinent parts of the experiment were repeated with antibody to -Val-Asp-Pro-Arg-Leu-Glu-Pro-Trp-Lys-His-Pro-Gly-Ser- (SEQ ID NO:28), and the results reported in Table 3 below. These detector peptides had a purity exceeding 70% by mass spectrometry and were not purified further.

*C. Immunization of rabbits*

The peptide conjugates were taken up in purified water and emulsified 1:1 with complete Freund's adjuvant (CFA) or incomplete Freund's adjuvant (IFA) (ANTIBODIES - A LABORATORY MANUAL, Eds. E. Harlow and P. Lane, Cold Spring Harbor Laboratory (1998)). Total volume per rabbit was 1 ml, and this contained 100 µg of peptide coupled to DT.

Two rabbits were used for the immunizing peptide, with the initial intramuscular (IM) injection with conjugate in CFA and a subsequent IM boost at 2 weeks with conjugate in IFA. A pre-bleed was drawn before the first injection and larger bleeds were taken 3 and 5 weeks after the booster injection.

*D. ELISA determination of binding of antisera to biotinylated peptides*

These assays were performed as described by H.M. Geysen *et al.*, Proc. Natl. Acad. Sci. USA, 81:3998 (1983). Briefly, using Nunc Immuno Maxisorb™ 96 well plates, biotinylated peptides were bound to streptavidin coated plates and, with washing with phosphate buffered saline (PBS) between steps, successive incubations were performed with antiserum dilutions and horseradish peroxidase conjugated anti-rabbit immunoglobulin to detect bound antibody. Plates were developed with ABTS, with an O.D. reading at 405 nm. Absorbance greater than O.D. 1.0 was taken as positive and titers were determined from doubling dilutions

of each antiserum. The geometric mean titer (GMT) was calculated for each antiserum pair for a given immunogen.

Table 2

Detector Sequence*	Antiserum to Epitope I: -Val-Asp-Pro-Arg-Leu-Glu-Pro-Trp-Lys-His-Pro-Gly-Ser-; GMT (% binding versus immunogen)	SEQ ID NO.
-Val-Asp-Pro-Arg-Leu-Glu-Pro-Trp-Lys-His-Pro-Gly-Ser-	65,885 (100)	31
-Asp-Pro-Arg-Leu-Glu-Pro-Trp-Lys-His-Pro-Gly-Ser-	83,753 (127)	32
-Val-Asp-Pro-Arg-Leu-Glu-Pro-Trp-	96,627 (147)	33
-Val-Asp-Pro-Arg-Leu-Glu-Pro-	80,960 (123)	34
-Val-Asp-Pro-Arg-Leu-Glu-	32,016 (49)	35

\*Substitution of Asp to Gly, Ala or His reduced titer to <1% (See Example 2)

Table 3

N Terminus	Detector Sequences	C Terminus	% binding	SEQ ID No
N0	Val-Asp-Pro-Arg-Leu-Glu-Pro- Trp-Lys-His-Pro-Gly-Ser-Gln-Pro- Lys-Thr-Ala-OH	C + 11	124	71
N0	Val-Asp-Pro-Arg-Leu-Glu-Pro- Trp-Lys-His-Pro-Gly-Ser-OH	C + 6	100	28
N0	Val-Asp-Pro-Arg-Leu-Glu-Pro- Trp-OH	C + 1	120	33
N0	Val-Asp-Pro-Arg-Leu-Glu-Pro- Trp-NH <sub>2</sub>	C + 1	134	92
N0	Val-Asp-Pro-Arg-Leu-Glu-Pro- NH <sub>2</sub>	C0	116	93
N0	Val-Asp-Pro-Arg-Leu-Glu-NH <sub>2</sub>	C - 1	47	94
N0	Val-Asp-Pro-Arg-Leu-OH	C - 2	5	95
N - 1	Asp-Pro-Arg-Leu-Glu-Pro- Trp-OH	C + 1	65	96
N - 2	Gly-Pro-Arg-Leu-Glu-Pro- Trp-OH	C + 1	1	97
N - 2	Ala-Pro-Arg-Leu-Glu-Pro- Trp-OH	C + 1	1	98

ELISA results reported in Tables 2 and 3 demonstrated that the antibodies to the first immunogen were reacting with the sequence -Asp-Pro-Arg-Leu-Glu-Pro (AA 5-10 of SEQ ID NO: 1). N- or C-terminal truncation of these sequences reduced the ELISA titer. From the results of Tables 2 and 3 taken together, the N-terminal Val of the Epitope I peptide makes a small contribution to antibody binding (deletion gives 65% of binding). Thus the definition of the primary antibody binding region of HIV-1 Tat, referred to herein as Epitope I, is: -Val-Asp-Pro-Arg-Leu-Glu-Pro- (SEQ ID NO:34).

*E. HIV-1 Tat Epitope I minimal sequence analysis*

The following experiment was performed using as the immunizing peptide sequence: Val-Asp-Pro-Arg-Leu-Glu-Pro-Trp-Lys-His-Pro-Gly-Ser -NH<sub>2</sub> (SEQ ID NO: 28). As demonstrated by the results in Table 3, the minimal sequence of Epitope I with maximal binding of antibody is confirmed as Val-Asp-Pro-Arg-Leu-Glu-Pro (SEQ ID NO:34). The variations in binding with C-terminal extensions are not significant. The truncation of N-terminal Val or C-terminal Pro lead to modest reduction of binding titers, but truncating beyond this leads to almost complete loss of specific binding, indicating that Asp-Pro-Arg-Leu-Glu (amino acids 5-9 of SEQ ID NO: 1) are the most important amino acids to create interactions with specific antibody (See, e.g., Fig. 3). GMT is reported as % of GMT on detector peptide containing the immunogen sequence.

*F. Effects of Epitope I Immunogen Extension on Antibody Titers*

N terminal extension of the epitope sequence in the immunogen does not affect immunogenicity. In contrast, C terminal extension up to Val-Asp-Pro-Arg-Leu-Glu-Pro-Trp-Lys-His-Pro-Gly-Ser-NH<sub>2</sub> (SEQ ID NO: 28) results in a 10-fold enhancement on titer. The present optimal immunizing sequence appears to be SEQ ID NO: 28. GMT on SEQ ID NO: 28 is reported as % of GMT of antisera to SEQ ID NO: 28 on this peptide, as shown in Table 4.

Table 4

N Terminus	Immunogen Sequence	C Terminus	% binding	Seq ID #
N0	Val-Asp-Pro-Arg-Leu-Glu-Pro - Trp-Lys-His-Pro-Gly-Ser-NH <sub>2</sub>	C+6	100	28
N+2	Glu-Pro-Val-Asp-Pro-Arg-Leu- Glu-Pro-Trp-Lys-His-Pro-Gly- Ser-OH	C+6	105	99
N0	Val-Asp-Pro-Arg-Leu-Glu-Pro- Trp-Lys-His-Pro-OH	C+4	10	100
N0	Val-Asp-Pro-Arg-Leu-Glu-Pro- Trp-Lys-OH	C+2	67	101
N0	Val-Asp-Pro-Arg-Leu-Glu-Pro- NH <sub>2</sub>	C0	9	102

*G. Binding Pattern of Antibodies Induced by N-terminally*

*Extended Immunogens*

The binding of antisera to Epitope I immunogens with N-terminal sequence extensions through the N-terminal Met were examined on detector peptides with full length and N- or C-terminal truncation. In these instances some of the immunizing peptides were synthesized with C-terminal Cys-amide for coupling to the carrier protein and corresponding detector peptides were synthesized with a C-terminal-Gly-Ser-Gly-Ser-biotin-amide (SEQ ID NO: 91) for binding to avidin coated plates.

**Table 5**

Antiserum to Met-Glu-Pro-Val-Asp-Pro-Arg-Leu-Glu-Pro-Trp-Lys-His-Pro-Gly-Ser-Gln-Pro-Lys-Thr-Ala- (amino acids 1-21 of SEQ ID NO: 1). Titers on N-terminal truncation peptides

Detector Peptide	Titer	% titer on longest peptide
Met-Glu-Pro-Val-Asp-Pro-Arg-Leu-Glu-Pro (amino acids 1-10 of SEQ ID NO: 1)	61,000	100
-Glu-Pro-Val-Asp-Pro-Arg-Leu-Glu-Pro (amino acids 2-10 of SEQ ID NO: 1)	54,000	89
-Pro-Val-Asp-Pro-Arg-Leu-Glu-Pro (amino acids 3-10 of SEQ ID NO: 1)	37,000	61
-Val-Asp-Pro-Arg-Leu-Glu-Pro (amino acids 4-10 of SEQ ID NO: 1)	19,000	22
-Pro-Arg-Leu-Glu-Pro (amino acids 6-10 of SEQ ID NO: 1)	9,000	11
-Arg-Leu-Glu-Pro (amino acids 7-10 of SEQ ID NO: 1)	581	<1

**Table 6**

Antiserum to Glu-Pro-Val-Asp-Pro-Arg-Leu-Glu-Pro-Trp-Lys-His-Pro-Gly-Ser (amino acids 2-16 of SEQ ID NO: 1). Titers on C-terminal truncation peptides

Detector Peptide	Titer	% titer on longest peptide
Met-Glu-Pro-Val-Asp-Pro-Arg-Leu-Glu-Pro (amino acids 1-10 of SEQ ID NO: 1)	112,000	100
Met-Glu-Pro-Val-Asp-Pro-Arg-Leu-Glu (amino acids 1-9 of SEQ ID NO: 1)	27,000	24
Met-Glu-Pro-Arg-Leu (amino acids 1-5 of SEQ ID NO: 1)	6,000	5

From the above data it is evident that N-terminal extension of the immunizing Epitope I peptide extends the antibody binding region through Glu<sub>2</sub> of the HIV-1 Tat protein sequence.

**Table 7**

Immunizing Peptide	Titer on : Met-Glu-Pro-Val-Asp-Pro-Arg-Leu-Glu-Pro (amino acids 1-10 of SEQ ID NO: 1)	Titer on: Val-Asp-Pro-Arg-Leu-Glu-Pro (amino acids 4-10 of SEQ ID NO: 1)
Val-Asp-Pro-Arg-Leu-Glu-Pro-Trp-Lys-His-Pro-Gly-Ser (amino acids 4-16 of SEQ ID NO: 1)	79,000	79,000
Glu-Pro-Val-Asp-Pro-Arg-Leu-Glu-Pro-Trp-Lys-His-Pro-Gly-Ser (amino acids 2-16 of SEQ ID NO: 1)	70,000	42,000
Met-Glu-Pro-Val-Asp-Pro-Arg-Leu-Glu-Pro-Trp-Lys-His-Pro-Gly-Ser-Gln-Pro-Lys-Thr-Ala (amino acids 1-21 of SEQ ID NO: 1)	61,000	19,000

These data show that very similar total anti-Tat antibody titers are obtained with the various N-terminal immunogens but with a slightly different distribution of the binding regions.

## EXAMPLE 2 - SEQUENCE VARIATIONS IN EPITOPE I OF HIV-1 TAT PROTEIN AND IMMUNOLOGICAL CROSS-REACTIVITIES OF ANTISERUMS TO THESE SEQUENCES

Variations in the sequence of Tat protein AA 5-10 of SEQ ID NO:1 were analyzed in sequences available in HUMAN RETROVIRUSES and AIDS 1996, published by the Theoretical Biology and Biophysics Group of the Los Alamos

National Laboratory, Los Alamos, NM, and additional sequences kindly obtained from GenBank by Esther Guzman of the Los Alamos Laboratory.

*A. Variations in sequences*

399 aa 5-10 Tat hexapeptide sequences of the common B subtype of HIV-1 were obtained, as were 18 from the non-B subtypes (6 from subtype A, 2 from subtype C, 7 from subtype D, 2 from subtype F and 1 from subtype U).

For the B subtype, 386 of the total 399 (97%) hexapeptides had either Arg (289, 74%), or Lys (45, 11%), or Ser (36, 9%) or Asn (16, 4%) in position 3 as the only variation in the hexapeptides. The remaining variations (3%) comprised:

10        -Gly-Pro-Arg-Leu-Glu-Pro- (4)        (SEQ ID NO: 11),  
           -Asp-Pro-Gly-Leu-Glu-Pro- (2)        (SEQ ID NO: 14),

and single examples of:

          -Asp-His-Arg-Leu-Glu-Pro-        (SEQ ID NO: 41),  
           -Ala-Pro-Arg-Leu-Glu-Pro-        (SEQ ID NO: 12),  
 15        -His-Pro-Arg-Leu-Glu-Pro-        (SEQ ID NO: 13),  
           -Asp-Pro-Arg-Ile-Glu-Pro-        (SEQ ID NO: 15),  
           -Asp-Pro-Arg-Leu-Gly-Pro-        (SEQ ID NO: 16),  
           -Asp-Pro-Arg-Leu-Glu-Ala-        (SEQ ID NO: 17) and  
           -Asn-Pro-Ser-Leu-Glu-Pro-        (SEQ ID NO: 18).

20                    For the 18 non-B subtype sequences, 2 had Arg, 1 had Lys, 2 had Ser and 9 had Asn at position 3 of the hexapeptides aa5-10, and other variants were

          -Asp-Pro-Asn-Leu-Asp-Pro- (2)        (SEQ ID NO: 42)

and single examples of

25            -Asp-Pro-Asn-Ile-Glu-Pro-        (SEQ ID NO: 43) and  
           -Asp-Pro-Asn-Leu-Glu-Ser-        (SEQ ID NO: 44).



*B. Assessment of immunological reactivity and cross-reactivity of the four primary immunogens*

Immunizing and detector sequences were synthesized, as described in Example 1, for the following sequences (SEQ ID NOS: 28 and 45 through 47, respectively):

-Val-Asp-Pro-Arg-Leu-Glu-Pro-Trp-Lys-His-Pro-Gly-Ser-,  
 -Val-Asp-Pro-Lys-Leu-Glu-Pro-Trp-Lys-His-Pro-Gly-Ser-,  
 -Val-Asp-Pro-Ser-Leu-Glu-Pro-Trp-Lys-His-Pro-Gly-Ser-,  
 -Val-Asp-Pro-Asn-Leu-Glu-Pro-Trp-Lys-His-Pro-Gly-Ser-.

Rabbits were immunized and the antiserums were tested by ELISA, as described in Example 1, for reactivity and cross-reactivity. Self-reactivities are summarized in Table 8.

**Table 8**

Immunogen and detector sequence	GMT	SEQ ID NO
-Val- <u>Asp-Pro-Arg-Leu-Glu-Pro</u> -Trp-Lys-His-Pro-Gly-Ser-	88,000	28
-Val- <u>Asp-Pro-Lys-Leu-Glu-Pro</u> -Trp-Lys-His-Pro-Gly-Ser-	132,000	45
-Val- <u>Asp-Pro-Ser-Leu-Glu-Pro</u> -Trp-Lys-His-Pro-Gly-Ser-	166,355	46
-Val- <u>Asp-Pro-Asn-Leu-Glu-Pro</u> -Trp-Lys-His-Pro-Gly-Ser-	173,097	47

Cross-reactivities between these primary immunogens with varying amino acid residues at position 3 of Epitope I are displayed in Table 9. Note that the results reported below are averages with one poorly reactive antiserum.

**Table 9**

Antiserums to primary immunogens (figures denote % reactivity v. self-reactivity)

<b>Detectors</b>	<b>Arg3</b>	<b>Lys3</b>	<b>Ser3</b>	<b>Asn3</b>
Arg3	100	49	3	4
Lys3	24	100	6	5
Ser3	11	16	100	15
Asn3	11	22	10	100

Tables 8 and 9 demonstrate that each variant is an effective immunogen, but in general there is only modest cross-reactivity between variants. The best cross-reactivity is obtained with the Lys 3-containing immunogen. This implies that optimal coverage would require inclusion of all four variants as immunogens in a primary composition as described above.

*C. Assessment of cross-reactivities of other variants.*

Detector peptides were made for all remaining epitope variants and tested for cross-reactivity with the antiserums to the appropriate position 3 primary hexapeptide immunogen. The cross-reactivities versus self-reactivity with the appropriate position 3 primary immunogen are displayed in Table 10.

Table 10

Reactivity	Detector Sequence (variations in Epitope I)	% Cross-reactivity	SEQ ID NO:
Cross-reactive	-Asp- <u>His</u> -Arg-Leu-Glu-Pro-	55	41
"	-Asp-Pro-Asn- <u>Ile</u> -Glu-Pro-	70	43
"	-Asp-Pro-Asn-Leu- <u>Asp</u> -Pro-	100	42
"	-Asp-Pro-Asn-Leu-Glu- <u>Ser</u> -	78	44
Non-cross reactive	- <u>Gly</u> -Pro-Arg-Leu-Glu-Pro-	1	11
"	- <u>Ala</u> -Pro-Arg-Leu-Glu-Pro-	1	12
"	- <u>His</u> -Pro-Arg-Leu-Glu-Pro-	1	13
"	-Asp-Pro- <u>Gly</u> -Leu-Glu-Pro-	1	14
"	-Asp-Pro-Arg- <u>Ile</u> -Glu-Pro-	9	15
"	-Asp-Pro-Arg-Leu- <u>Gly</u> -Pro-	10	16
"	-Asp-Pro-Arg-Leu-Glu- <u>Ala</u> -	1	17
"	- <u>Asn</u> -Pro-Ser-Leu-Glu-Pro-	10	18

The results of Tables 8-10 indicate that immunization with the four primary immunogens would generate antibodies reactive with greater than 97% of HIV-1 Tat proteins of the common B subtype. Interestingly all 18 non-B subtypes in the databases had Epitope I sequences reactive with antibodies to the primary immunogens.

*D. Immunogenicity of certain Epitope I variants*

Immunizing and detecting peptides were synthesized for the following 2 variant Epitope I peptides, with immunizations and ELISA testing as in Example 1. The self titers (GMT) are displayed in Table 11.

Table 11

Detecting and Immunizing Peptides (GMT)	Self-titer	SEQ ID NOS.
-Val- <u>Asn</u> -Pro-Ser-Leu-Glu-Pro-Trp-Lys-His-Pro-Gly-Ser-	94,919	48
-Val-Asp- <u>His</u> -Arg-Leu-Glu-Pro-Trp-Lys-His-Pro-Gly-Ser-	72,686	49

These data show that inclusion of rare variants along with the primary immunogens expands antibody coverage to such rare epitope variants.

Immunization with the four primary Epitope I sequences can induce high titer antibodies reactive with Tat proteins of >97% of all HIV-1 strains. This coverage can be optionally extended with the inclusion of additional rare Epitope I variant sequences in the immunizing composition.

*E. Consequences of N-terminal immunogen extension on immunological conservation and cross-reactivity*

Reviewing the Epitope I sequences studied above, the major variation in the Glu-Pro- extension is the occurrence of an Asp for Glu substitution in 9% of sequences. However, as shown in Table 12, antibodies to Glu containing peptides are substantially cross-reactive with the corresponding Asp containing peptide, and vice-versa.

Table 12

Immunogens	Detector Peptides (Titer)		
	Met-Glu-Pro-Val-Asp-Pro-Arg-Leu-Glu-Pro (amino acids 1-10 of SEQ ID NO:1)	Met-Asp-Pro-Val-Asp-Pro-Arg-Leu-Glu-Pro (SEQ ID NO: 103)	Val-Asp-Pro-Arg-Leu-Glu-Pro (amino acids 4-10 of SEQ ID NO:1)
Met-Glu-Pro-Val-Asp-Pro-Arg-Leu-Glu-Pro-Trp-Lys (amino acids 1-12 of SEQ ID NO: 1)	82,000	67,000	38,000
Met-Asp-Pro-Val-Asp-Pro-Arg-Leu-Glu-Pro-Trp-Lys (SEQ ID NO: 104)	50,000	75,000	38,000

Other than the variation between Glu and Asp there were only 7 other variants at these two positions (5 Lys/Glu and 2 Leu-Pro substitutions), bringing the immunological conservation of the enlarged Epitope I in B subtype HIV-1 Tat proteins to 95%. For the 18 non B subtype sequences only 16 contained sequence corresponding to the Glu-Pro extension and, apart from Glu/Asp variation, all were Glu-Pro or Asp-Pro except for two F subtype sequences (Glu-Leu), yielding an immunological conservation of 88%. Thus immunization with peptides with extended N-terminal sequence still provides a high incidence of immunoreactivity with a broad sample of known HIV-1 Tat protein sequences.

**EXAMPLE 3 - DEFINING AN ANTIBODY BINDING AMINO ACID SEQUENCE (EPITOPE II) WITHIN THE LINEAR 18 AMINO ACID SEQUENCE FOLLOWING CYS<sub>37</sub> OF HIV-1 TAT PROTEIN.**

A peptide corresponding to amino acids 38-55 of SEQ ID NO: 1 illustrated in Fig. 1 was synthesized as described in Example 1. Using the methods described in Example 1, a low titer antibody response in rabbits was detected and

Table 28 summarizes studies defining the sequence involved in this antibody binding. The geometric mean titer (GMT) is reported as percentage of self-titer.

**Table 13**

5 Antiserum to SEQ ID NO: 105:

Phe-Ile-Thr-Lys-Gly-Leu-Gly-Ile-Ser-Tyr-Gly-Arg-Lys-Lys-Arg-Arg-Gln-Arg

	Detector Peptides	GMT (% self titer)	SEQ ID NO.
10	Phe-Ile-Thr-Lys-Gly-Leu-Gly-Ile-Ser-Tyr-Gly-Arg-Lys-Lys-Arg-Arg-Gln-Arg	947 (100)	105
	Phe-Ile-Thr-Lys-Gly-Leu-Gly-Ile-Ser-Tyr-Gly-Arg-Lys-Lys-Arg	1141 (115)	(amino acids 1-15 of SEQ ID NO: 105)
	Lys-Gly-Leu-Gly-Ile-Ser-Tyr-Gly-Arg-Lys-Lys-Arg-Arg-Gln-Arg	895 (95)	(amino acids 41-55 of SEQ ID NO: 1)
15	Leu-Gly-Ile-Ser-Tyr-Gly-Arg-Lys-Lys-Arg-Arg-Gln-Arg	986 (104)	(amino acids 43-55 of SEQ ID NO: 1)
	Gly-Ile-Ser-Tyr-Gly-Arg-Lys-Lys-Arg	428 (47)	(amino acids 44-52 of SEQ ID NO: 1)
20	Ile-Ser-Tyr-Gly-Arg-Lys-Lys-Arg	254 (27)	(amino acids 45-52 of SEQ ID NO: 1)
	Ser-Tyr-Gly-Arg-Lys-Lys-Arg-Arg-Gln-Arg	53 (6)	(amino acids 46-55 of SEQ ID NO: 1)
	Leu-Gly-Ile-Ser-Tyr-Gly-Arg-Lys-Lys	914 (97)	(amino acids 43-51 of SEQ ID NO: 1)
	Leu-Gly-Ile-Ser-Tyr-Gly-Arg-Lys	545 (58)	(amino acids 43-50 of SEQ ID NO: 1)
25	Phe-Ile-Thr-Lys-Gly-Leu-Gly-Ile-Ser-Tyr-Gly-Arg	129 (14)	(amino acids 1-12 of SEQ ID NO: 105)

These ELISA results established that the low titer antibodies induced bound to the sequence Leu-Gly-Ile-Ser-Tyr-Gly-Arg-Lys-Lys (amino acids 43-51 of SEQ ID NO: 1). Accordingly, this sequence and the sequence Lys-Gly-Leu-Gly-Ile-Ser-Tyr-Gly-Arg-Lys-Lys (amino acids 41-51 of SEQ ID NO: 1) were synthesized and used to immunize rabbits.

Immunizing with the minimal epitope, Leu-Gly-Ile-Ser-Tyr-Gly-Arg-Lys-Lys (amino acids 43-51 of SEQ ID NO: 1), produced low titer antibodies (GMT 1,000) while, surprisingly, immunization with Lys-Gly-Leu-Gly-Ile-Ser-Tyr-Gly-Arg-Lys-Lys (amino acids 41-51 of SEQ ID NO: 1) induced high titer antibodies (GMT 20,000) to the detector peptide Phe-Ile-Thr-Lys-Gly-Leu-Gly-Ile-Ser-Tyr-Gly-Arg-Lys-Lys-Arg-Arg-Gln-Arg (SEQ ID NO: 105).

The variation of sequence occurring within Epitope II was analyzed to enable the design of immunogens that induce antibodies that react with most Epitope II sequences. 441 sequence variations were determined in HIV-1 Tat protein amino acids 41-51 of the common B subtype were obtained, as were 21 from non-B subtypes (7 from subtype A, 4 from subtype C, 7 from subtype D, 2 from subtype F and 1 from subtype U). For the B subtype, 422 of 441 (96%) had the nominal sequence with the exception of an Ala for Gly substitution in 134 (32%). For the non-B subtype sequences 20 of 21 (95%) had the nominal sequence.

The reactivity of antibodies induced by Lys-Gly-Leu-Gly-Ile-Ser-Tyr-Gly-Arg-Lys-Lys (amino acids 41-51 of SEQ ID NO: 1) was studied by titrating antisera to Lys-Gly-Leu-Gly-Ile-Ser-Tyr-Gly-Arg-Lys-Lys (amino acids 41-51 of SEQ ID NO: 1) as follows on the listed detector peptides:

Table 14

Detector Peptides	Titer	SEQ ID NO.
Phe-Ile-Thr-Lys-Gly-Leu-Gly-Ile-Ser-Tyr-Gly-Arg-Lys-Lys-Arg-Arg-Gln-Arg	20,000	105
Lys-Gly-Leu-Gly-Ile-Ser-Tyr-Gly-Arg-Lys-Lys-Arg-Arg-Gln-Arg	18,000	(amino acids 4-18 of SEQ ID NO: 105)
Lys-Ala-Leu-Gly-Ile-Ser-Tyr-Gly-Arg-Lys-Lys	20,000	106
Leu-Gly-Ile-Ser-Tyr-Gly-Arg-Lys-Lys	19,000	(amino acids 3-11 of SEQ ID NO: 106)

These data show that there is full immunological cross reactivity with the Ala variant and that the antibody response to Lys-Gly-Leu-Gly-Ile-Ser-Tyr-Gly-Arg-Lys-Lys (amino acids 41-51 of SEQ ID NO: 1) remains directed to the previously identified epitope Leu-Gly-Ile-Ser-Tyr-Gly-Arg-Lys-Lys (amino acids 43-51 of SEQ ID NO: 1). Thus immunization with Lys-Gly-Leu-Gly-Ile-Ser-Tyr-Gly-Arg-Lys-Lys (amino acids 41-51 of SEQ ID NO: 1) induces high titer antibodies which react with greater than 96% of known HIV-1 Tat proteins.

#### EXAMPLE 4 - IMMUNOLOGICAL STUDIES ON MINIMAL TAT PROTEIN AMINO ACID SEQUENCES NECESSARY FOR BINDING TO ANTIBODY FOR EPITOPE III IN HIV-1 TAT PROTEIN

A peptide was synthesized which corresponded to amino acids 53-62 of SEQ ID NO: 1 illustrated in Fig. 1 as described below. The sequence is the most frequent sequence representations at these positions in 31 Tat protein sequences of the common B subtype reported in the NIAID HIV database. The sequence was chosen as a second putative immunogen.

##### A. Peptide synthesis - Immunizing peptides

The amino acid sequences of the immunogen, -Arg-Gln-Arg-Arg-Arg-Ala-Pro-Gln-Asp-Ser- (SEQ ID NO: 29) was synthesized as described in Example 1 for Epitope I. The experiments for which data is reported are represented



in Tables 15-16 below. Immunizing peptides were generally purified to greater than 95% purity by reverse phase HPLC, and purity was further confirmed by mass spectrometry (MS). Immunizing peptides were covalently coupled to diphtheria toxoid (DT) carrier protein via the cysteinyl side chain as described for Epitope I in Example 1A.

*B. Peptide synthesis - Detector peptides*

Peptides corresponding to the amino acid sequence of the immunogen peptide were synthesized by the method of Geysen, cited above, for use in ELISA assays for detection of reactivity and cross-reactivity. Additional peptides with N- and C-terminal truncations were also synthesized. For most of the experiments reported below in Table 15, detector peptides had an N-terminal -Ser-Gly-Ser-Gly- (SEQ ID NO: 30) added, with biotinylation of the new N-terminus, and the C-terminal remained a free acid. These detector peptides had a purity exceeding 70% by mass spectrometry and were not purified further.

*C. Immunization of rabbits*

The peptide conjugates were taken up in purified water and emulsified 1:1 with CFA or IFA as described in Example 1C. Total volume per rabbit was 1 ml, and this contained 100 µg of peptide coupled to DT. Two rabbits were used for the immunizing peptide, with the initial intramuscular (IM) injection with conjugate in CFA and a subsequent IM boost at 2 weeks with conjugate in IFA. A pre-bleed was drawn before the first injection and larger bleeds were taken 3 and 5 weeks after the booster injection.

*D. ELISA determination of binding of antisera to biotinylated peptides*

These assays were performed as described by H.M. Geysen *et al.*, Proc. Natl. Acad. Sci. USA, 81:3998 (1983) and as described in Example 1D for Epitope I. From the results of Table 15, the definition of another antibody binding region of HIV-1 Tat, referred to herein as Epitope III, is -Arg-Arg-Ala-Pro-Gln-Asp-Ser- (SEQ ID NO: 19).

*E. HIV-1 Tat Epitope III minimal sequence analysis*

The following experiment was performed using as the immunizing peptide sequence: Arg-Gln-Arg-Arg-Arg-Ala-Pro-Gln-Asp-Ser-NH<sub>2</sub> (SEQ ID NO:29). The results in the following Table 15 illustrate that the minimal sequence of Epitope III with maximal binding of antibody is Arg-Arg-Ala-Pro-Gln-Asp-Ser (SEQ ID NO: 19). N-terminal or C-terminal extensions of the detector peptides do not produce significantly different binding. The truncation of N-terminal Arg leads to a modest reduction of binding titer, while truncation of the next N-terminal Arg or the C-terminal Ser lead to almost complete loss of specific binding, indicating that Arg-Ala-Pro-Gln-Asp-Ser (amino acids 57-62 of SEQ ID NO: 1) are the most important amino acids to create interactions with specific antibody (See Fig. 4). GMT is reported as % GMT on detector peptide containing the immunogen sequence.

10086208, 022802

Table 15

N Term	Detector Sequences	C Term	% binding	SEQ ID #
N+3	Arg-Gln-Arg-Arg-Arg-Ala-Pro-Gln-Asp-Ser-OH	C0	100	(amino acids 53-62 of SEQ ID NO: 1)
N+2	Gln-Arg-Arg-Arg-Ala-Pro-Gln-Asp-Ser-OH	C0	94	(amino acids 54-62 of SEQ ID NO: 1)
N+1	Arg-Arg-Arg-Ala-Pro-Gln-Asp-Ser-OH	C0	93	(amino acids 55-62 of SEQ ID NO: 1)
N0	Arg-Arg-Ala-Pro-Gln-Asp-Ser-OH	C0	105	(amino acids 56-62 of SEQ ID NO: 1)
N0	Arg-Arg-Ala-Pro-Gln-Asp-Ser-Gln-Thr-His-Gln-OH	C+4	107	(amino acids 56-66 of SEQ ID NO: 1)
N-1	Arg-Ala-Pro-Gln-Asp-Ser-OH	C0	56	(amino acids 57-62 of SEQ ID NO: 1)
N-2	Ala-Pro-Gln-Asp-Ser-OH	C0	3	(amino acids 58-62 of SEQ ID NO: 1)
N+3	Arg-Gln-Arg-Arg-Arg-Ala-Pro-Gln-Asp-OH	C-1	7	(amino acids 53-61 of SEQ ID NO: 1)
N+3	Arg-Gln-Arg-Arg-Arg-Ala-Pro-Gln-OH	C-2	4	(amino acids 53-60 of SEQ ID NO: 1)

*F. HIV-1 Tat Epitope III - Effects of Immunogen on Antibody Titers*

Every instance of C-terminal extension results in loss of immunogenicity and lowered titers. In contrast, N terminal extension up to a point enhances immunogenicity, with maximal titers being obtained with Gln-Arg-Arg-Arg-Ala-Pro-Gln-Asp-Ser (amino acids 54-62 of SEQ ID NO: 1) and a drop in immunogenicity occurring with Arg-Arg-Gln-Arg-Arg-Arg-Ala-Pro-Gln-Asp-Ser- (amino acids 52-62 of SEQ ID NO: 1) as the immunogen. GMT on Arg-Gln-Arg-Arg-Arg-Ala-Pro-Gln-Asp-Ser- (amino acids 53-62 of SEQ ID NO: 1) is reported in Table 16 as % of GMT of antisera to this peptide on this detector peptide.

Table 16

N Term	Immunogen Sequence	C Term	% binding	SEQ ID #
N+3	Arg-Gln-Arg-Arg-Arg-Ala-Pro-Gln-Asp-Ser-NH <sub>2</sub>	C0	100	107
N+1	Gly-Arg-Arg-Ala-Pro-Gln-Asp-Ser-NH <sub>2</sub>	C0	11	108
N0	Arg-Arg-Ala-Pro-Gln-Asp-Ser-Gln-Thr-His-Gln-NH <sub>2</sub>	C+4	3	109
N+2	Gln-Arg-Arg-Arg-Ala-Pro-Gln-Asp-Ser-OH	C0	136	(amino acids 54-62 of SEQ ID NO: 1)
N+3	Arg-Gln-Arg-Arg-Arg-Ala-Pro-Gln-Asp-Ser-Gln-Thr-OH	C+2	9	(amino acids 53-64 of SEQ ID NO: 1)
N+3	Arg-Gln-Arg-Arg-Arg-Ala-Pro-Gln-Asp-Ser-Gln-Thr-His-Gln-OH	C+4	28	(amino acids 53-66 of SEQ ID NO: 1)
N+4	Arg-Arg-Gln-Arg-Arg-Arg-Ala-Pro-Gln-Asp-Ser-OH	C0	3	(amino acids 52-62 of SEQ ID NO: 1)

EXAMPLE 5 - SEQUENCE VARIATIONS IN EPITOPE III OF HIV-1 TAT PROTEIN AND IMMUNOLOGICAL CROSS-REACTIVITIES OF ANTISERUMS TO THESE SEQUENCES

Variations in the sequence of Tat protein AA 56-72 were analyzed in sequences available in HUMAN RETROVIRUSES and AIDS 1996, (cited above) and additional sequences (GenBank), as described in Example 4.

A. *Variations in Epitope III sequences*

482 sequences of Epitope III of the common B subtype of HIV-1 were available for analysis. The most frequent sequence found conformed to the formula -Arg-Arg-X-Pro-Gln-Y-Ser- (SEQ ID NO: 110), where X is Ala, Pro, Ser, or Gln, and Y is Asp, Asn, Gly or Ser. This sequence type, which appears

immunologically cross-reactive (see below), was found in 292 of 482 (61%) of available Tat sequences.

Other sequence variants occurred in lower incidence and these included those listed in Table 17 below.

**Table 17**

SEQUENCES	# (%) of Tat Sequences	SEQ ID NO.
-Arg-Arg-Ala-Pro-Pro-Asp-Ser-	20 (4%)	20
-Arg-Arg-Ala-Pro-Pro-Asp-Asn-	21 (4%)	50
-Arg-Arg-Ala-His-Gln-Asp-Ser-	20 (4%)	21
-Arg-Arg-Ala-His-Gln-Asn-Ser-	17 (3.5%)	22
-Arg-Arg-Ala-Pro-Gln-Gly-Asn-	10 (2%)	51
-Arg-Gly-Ala-Pro-Gln-Asp-Ser-	9 (2%)	25
-Arg-Arg-Ala-Pro-Glu-Asp-Ser-	8 (2%)	26
-Arg-Arg-Ala-Ser-Gln-Asp-Ser-	8 (2%)	27
-Arg-Arg-Pro-Pro-Gln-Asp-Asn-	9 (2%)	23
-Arg-Arg-Ala-Pro-Gln-Asp-Arg-	8 (2%)	24

Together these sequences account for 85% of Epitope III variants, with the balance comprised of a large number of low incidence variations.

Epitope III sequences were only available from 18 examples of HIV-1 non-B subtypes. Unlike Epitope I, they showed divergence from the B subtype sequences and optionally a larger number of sequences can be selected for inclusion into the composition of this invention, if additional non-B subtype Epitope III sequences are determined and are desirable in an immunogenic composition of this invention.

*B. Assessment of immunological reactivity and cross reactivity of selected Epitope III sequences*

Immunizing and detector sequences were synthesized, as described in Example 1, for the sequences in Table 18. Rabbits were immunized and antiserums were tested by ELISA, as described in Example 4, for reactivity and cross-reactivity. The various antiserums and detector peptides were utilized to determine immunogenicity of the various sequences and the extent of immunological cross reactivity. The incidence and immunological reactivity of Epitope III sequences of the formula -Arg-Arg-X-Pro-Gln-Y-Ser- (SEQ ID NO: 10) (see above) are shown in Table 18. In Table 18 below, percent cross-reactivity was measured with antiserum to Cys-Arg-Gln-Arg-Arg-Arg-Ala-Pro-Gln-Asp-Ser- (SEQ ID NO: 74), self titer = 46,115. The results of Table 18 demonstrate that immunization with -Arg-Gln-Arg-Arg-Arg-Ala-Pro-Gln-Asp-Ser- (SEQ ID NO: 29) should provide effective cross-reactivity with most of these variants, represented in 61% of HIV-1 strains.

Table 18

	Epitope III Sequence	# per 482 sequences	% Cross-reactivity	SEQ ID NO.
	-Arg-Arg-Ala-Pro-Gln-Asp-Ser-	93	100	19
	-Arg-Arg-Pro-Pro-Gln-Asp-Ser-	50	111	75
5	-Arg-Arg-Pro-Pro-Gln-Asn-Ser-	41	96	76
	-Arg-Arg-Pro-Pro-Gln-Gly-Ser-	37	97	77
	-Arg-Arg-Ser-Pro-Gln-Asp-Ser-	19	93	73
	-Arg-Arg-Thr-Pro-Gln-Gly-Ser-	14	56	68
	-Arg-Arg-Ala-Pro-Gln-Gly-Ser-	9	87	69
10	-Arg-Arg-Thr-Pro-Gln-Asp-Ser-	7	116	70
	-Arg-Arg-Ala-Pro-Gln-Asn-Ser-	5	128	72
	-Arg-Arg-Ser-Pro-Gln-Asp-Ser-	4	110	73
	-Arg-Arg-Ser-Pro-Gln-Asn-Ser-	2	142	78
	-Arg-Arg-Ala-Pro-Gln-Ser-Ser-	1	97	79
15	-Arg-Arg-Ser-Pro-Gln-Gly-Ser-	1	78	80
	-Arg-Arg-Thr-Pro-Gln-Asn-Ser-	1	43	81

292/482 (61%)

Immunization with -Arg-Arg-Ala-Pro-Pro-Asp-Asn- (SEQ ID NO: 50) and -Arg-Arg-Ala-Pro-Pro-Asp-Ser- (SEQ ID NO: 20) yielded antibodies that cross-reacted with both detector peptides, as shown in Table 19. Thus, inclusion of either sequence in an immunizing composition of this invention provides antibodies against Tat protein Epitope III variants in a further 41/482 (8.5%) of HIV-1 strains.

Immunization with -Arg-Gln-Arg-Arg-Arg-Ala-His-Gln-Asn-Ser- (SEQ ID NO: 52) (20/482 (4%)) induced antibodies that gave a self titer of 209,286 and a cross-reactivity of 5,356 (2.5%) with -Arg-Arg-Ala-His-Gln-Asp-Ser- (SEQ ID NO: 21) (17/482 (3.5%)). Thus inclusion of this sequence in an immunogen covers an additional 27/482 (7.5%) of HIV-1 strains.

Thus, immunization with three Epitope III variants,  
 -Arg-Arg-Ala-Pro-Gln-Asp-Ser- (SEQ ID NO: 19),  
 -Arg-Arg-Ala-Pro-Pro-Asp-Asn- (SEQ ID NO: 50), and  
 -Arg-Arg-Ala-His-Gln-Asn-Ser- (SEQ ID NO: 22), provides  
 5 antibodies reactive with the Tat proteins of 77% of HIV-1 strains.

Table 19

Antiserum to:	Detector peptides ELISA GMT	
	-Arg-Arg-Ala-Pro-Pro-Asp- Asn- (SEQ ID NO: 50)	-Arg-Arg-Ala-Pro-Pro-Asp- Ser- (SEQ ID NO: 20)
SEQ ID NO: 50	11,056	12,230
SEQ ID NO: 20	9,340	7,865

#### EXAMPLE 6 - IMMUNOLOGICAL STUDIES ON MINIMAL TAT PROTEIN AMINO ACID SEQUENCES NECESSARY FOR BINDING TO ANTIBODY FOR EPITOPE IV IN HIV-1 TAT PROTEIN

A publication by McPhee et al, FEBS Letters 233:393 (1988) suggested  
 20 that some serums of HIV-1 infected subjects reacted with a synthetic peptide Ser-Gln-  
 Thr-His-Gln-Val-Ser-Leu-Ser-Lys-Gln-Pro-Cys (SEQ ID NO: 111), erroneously  
 reported as amino acids 71-83 of HIV-1 Tat protein (the correct positions are amino  
 acids 61-73). The inventor therefore immunized mice with the synthetic peptide-Ser-  
 Gln-Thr-His-Gln-Val-Ser-Leu-Ser-Lys-Gln-Pro (SEQ ID NO: 112) and determined  
 25 that antibodies reactive with this peptide were generated, with a geometric mean titer  
 of 26,517.

To determine minimal epitope size, a series of truncated peptides were  
 synthesized and used as detector peptides to determine minimal sequence length  
 requirements for binding. Table 20 reports the detector peptides and percent binding,  
 30 determined as described in Example 1 for Epitope I.



**Table 20**

Detector Peptides	% Binding	SEQ ID NO
-Ser-Gln-Thr-His-Gln-Val-Ser-Leu-Ser-Lys-Gln-Pro-(GMT 26,517)	100	112
-Gln-Thr-His-Gln-Val-Ser-Leu-Ser-Lys-Gln-Pro-	63	(amino acids 2-12 of SEQ ID NO: 112)
-Thr-His-Gln-Val-Ser-Leu-Ser-Lys-Gln-Pro-	42	(amino acids 3-12 of SEQ ID NO: 112)
-His-Gln-Val-Ser-Leu-Ser-Lys-Gln-Pro-	16	(amino acids 4-12 of SEQ ID NO: 112)
-Gln-Val-Ser-Leu-Ser-Lys-Gln-Pro-	5	(amino acids 5-12 of SEQ ID NO: 112)
-Ser-Gln-Thr-His-Gln-Val-Ser-Leu-Ser-Lys-Gln-	15	(amino acids 1-11 of SEQ ID NO: 112)
-Ser-Gln-Thr-His-Gln-Val-Ser-Leu-Ser-Lys-	3	(amino acids 1-10 of SEQ ID NO: 112)

From these data, it is clear that all 12 amino acids are necessary for full binding to Epitope IV, although the contribution of amino acids in positions 1 and 2 are not major.

The following determinations were made about sequence variations in Epitope IV and immunological cross-reactivities of antiserums, following the procedures described above for Epitopes I, II and III. 444 examples of this sequence region were available in the data bases. The most common variations were Asn for Thr at position 3 and Ala for Val at position 6. Reactivities of the antiserums to the nominal peptide to detector peptides corresponding to these sequences were studied as described above, and the results of percent binding reported in Table 21 below.

**Table 21**

Detector Peptides	% Binding	SEQ ID NO.
-Ser-Gln-Thr-His-Gln-Val-Ser-Leu-Ser-Lys-Gln-Pro-(GMT 26,517)	100	112
-Ser-Gln-Asn-His-Gln-Val-Ser-Leu-Ser-Lys-Gln-Pro-	85	113
-Ser-Gln-Thr-His-Gln-Ala-Ser-Leu-Ser-Lys-Gln-Pro-	17	114

Thus amino acid position 3 substitution from Thr to Asn does not materially affect antibody binding, whereas an Ala for Val substitution at amino acid position 6 is essentially non cross-reactive. In the 444 examples of HIV-1 Tat proteins sequenced in this region 282/444 (64%) had sequences that were similar to the nominal sequence. Disregarding amino acid 3 variations between Thr and Asn, 199/444 (45%) had Val as amino acid 6 and 83/444 (19%) had Ala as amino acid 6. In contrast to the poor cross-reactivity of Ala6 peptides with antisera to the Val6 immunogen, antisera to Ala6 peptide gave titers of 26,000 on the Ala6 peptide, and 32,000 on the Val6 peptide, demonstrating complete cross-reactivity.

Thus immunization with proteins containing the amino acid sequence - Ser-Gln-Thr-His-Gln-Ala-Ser-Leu-Ser-Lys-Gln-Pro- (SEQ ID NO: 114) provokes antibodies reactive with 64% of variant HIV-1 Tat proteins.

#### EXAMPLE 7 - CONSTRUCTION OF A SYNTHETIC GENE OF THE INVENTION

A synthetic gene was constructed that incorporated in frame eight Epitope I variants (including the four primary immunogens of the invention) and thirteen Epitope III variants, these constituting all the variant Epitope I and Epitope III sequences found in the Tat protein sequences of 31 HIV-1 B subtype strains reported in the 1996 HUMAN RETROVIRUSES and AIDS compilation, cited above. These included amino acids 4-16 for Epitope I and 53-62 for Epitope III, using the

numbering of SEQ ID NO: 1 illustrated in Fig. 1. The epitope sequences were separated by dipeptide spacers containing Gly and/or Ser residues.

The sequence of this one exemplary gene of this invention is shown in Figs. 2A-2C (SEQ ID NOS: 2 and 3). The gene was assembled as described in W.P.C. Stemmer et al., *Gene*, 164:49 (1995). Briefly, eleven top strand 60-mer oligonucleotides (oligos) and eleven bottom strand oligos with 20 nucleotide (nt) overlaps were synthesized along with two end 50-mers. The twenty-two 60-mers were incubated together under hybridizing conditions and polymerase chain reaction (PCR) was used to fill in the sequence and amplify it. The end 50-mers were then added and the assembly completed by PCR, with isolation of the full length gene on agarose gel.

The gene was sequenced and found to have the correct sequence within the actual epitopes, with the exception of an Ala to Thr substitution at position 136 (see Figs. 2A-2C). This was accepted since this change does not affect antibody binding of Epitope III (see Example 4).

This gene was then excised with restriction enzymes and inserted into the expression vector pBAD (L-M. Guzman et al., *J. Bacteriol*, 177:4121 (1990)) containing, in frame, the sequence for green fluorescent protein (GFP) (A. Cramer et al., *Nature Biotech*, 14:315 (1996)). TG1 *E. coli* were transfected and green-fluorescent colonies were isolated.

The isolated colonies were grown and expression was induced. Protein from each of three colonies had fluorescent bands on Western blotting with the expected molecular size (i.e., twice that of GFP alone). The resulting protein was soluble and was purified by nickel column affinity purification utilizing a hexa-histidyl that had been incorporated in the sequence.

Yield was approximately 1 mg protein per liter of supernatant after double affinity purification to yield >90% purity.

EXAMPLE 8 - IMMUNOLOGICAL CHARACTERIZATION OF THE  
RECOMBINANT FUSION PROTEIN EXPRESSING HIV-1 TAT PROTEIN  
EPITOPE VARIANTS

A. *Reactivity of fusion protein with rabbit antiserums to Epitope I  
and 2 variants.*

Rabbit antiserums generated to synthetic peptides corresponding  
to the four primary Epitope I sequences and four Epitope III sequences (see below)  
were tested by ELISA, using the methodology described in Examples 1 and 4, except  
that the plates were initially directly coated with a 100 µg/ml solution of antiserums  
with the fusion protein.

Table 22

Antiserum to:	Titers on fusion protein	SEQ ID NOS
-Val-Asp-Pro-Arg-Leu-Glu-Pro-Trp-Lys-His-Pro- Gly-Ser-	>>8000	28
-Val-Asp-Pro-Asn-Leu-Glu-Pro-Trp-Lys-His-Pro- Gly-Ser-	>>8000	47
-Val-Asp-Pro-Lys-Leu-Glu-Pro-Trp-Lys-His-Pro- Gly-Ser-	>>8000	45
-Val-Asp-Pro-Ser-Leu-Glu-Pro-Trp-Lys-His-Pro- Gly-Ser-	>8000	46
-Arg-Gln-Arg-Arg-Arg-Ala-Pro-Gln-Asp-Ser-	7000	29
-Arg-Gln-Arg-Arg-Arg-Ala-His-Gln-Asn-Ser-	>>8000	52
-Arg-Gln-Arg-Arg-Arg-Pro-Pro-Gln-Asp-Ser-	>8000	53
-Arg-Gln-Arg-Gln-Arg-Ala-Pro-Asp-Ser-Ser-	8000	82

These data show that the variant epitope sequences, expressed  
as a linear recombinant fusion protein, are expressed in a conformation recognizable by  
antibodies to the corresponding synthetic peptides.

*B. Immunization of mice with the fusion protein*

Three mice were immunized with 10 $\mu$ g each of an aqueous solution of the fusion protein of Example 7 emulsified with an equal volume of Freund's complete adjuvant, given intraperitoneally. Two weeks later they were similarly boosted, except that Freund's incomplete adjuvant was used. Serums were obtained three weeks later.

*C. ELISA testing of antiserums to the fusion protein with synthetic peptides corresponding to the epitope variants incorporated in the fusion protein*

ELISA testing was performed as described in Example 1 except that horseradish peroxidase conjugated anti-mouse immunoglobulin was used to detect antibody binding. The results are summarized in Table 23 below. These data demonstrate that both Epitope I and Epitope III sequences are expressed in the linear fusion protein, and react with antibodies to the synthetic sequences (see above). Antibodies to Epitope I were detectably induced by the recombinant fusion protein under the conditions of this experiment in mice. The failure of Epitope III sequences expressed within this linear peptide is in keeping with the findings with synthetic peptides, wherein C-terminal extension of the immunogen diminishes the resulting antibody titer (see Example 4).

Table 23

Detector peptides	Titer with antiserum to fusion protein	SEQ ID NO
-Val-Asp-Pro-Arg-Leu-Glu-Pro-Trp-Lys-His-Pro-Gly-Ser	2218	28
-Val-Asp-Pro-Asn-Leu-Glu-Pro-Trp-Lys-His-Pro-Gly-Ser-	3158	47
-Val-Asp-Pro-Lys-Leu-Glu-Pro-Trp-Lys-His-Pro-Gly-Ser-	2440	45
-Val-Asp-Pro-Ser-Leu-Glu-Pro-Trp-Lys-His-Pro-Gly-Ser-	3031	46
-Val-Asn-Pro-Ser-Leu-Glu-Pro-Trp-Lys-His-Pro-Gly-Ser-	3718	48
-Val-Asp-His-Arg-Leu-Glu-Pro-Trp-Lys-His-Pro-Gly-Ser-	3223	49
-Arg-Gln-Arg-Arg-Arg-Ala-Pro-Gln-Asp-Ser-	background	29
-Arg-Gln-Arg-Arg-Arg-Ala-His-Gln-Asn-Ser-	background	52
-Arg-Gln-Arg-Arg-Arg-Pro-Pro-Gln-Asp-Ser-	background	53
-Arg-Gln-Arg-Gln-Arg-Ala-Pro-Asp-Ser-Ser-	background	82
-Arg-Gln-Arg-Arg-Arg-Ala-Pro-Glu-Asp-Ser-	background	83
-Arg-Gln-Arg-Arg-Arg-Pro-Pro-Gln-Gly-Ser-	background	59
-Arg-Gln-Arg-Arg-Gly-Pro-Pro-Gln-Gly-Ser-	background	60
-Arg-Gln-Arg-Arg-Arg-Pro-Pro-Gln-Asn-Ser-	background	61
-Arg-Gln-Arg-Arg-Arg-Ser-Pro-Gln-Asp-Ser-	background	62
-Arg-Gln-Arg-Arg-Arg-Ser-Pro-Gln-Asn-Ser-	background	63
-Arg-Gln-Arg-Arg-Arg-Thr-Pro-Gln-Ser-Ser-	background	64
-Arg-Gln-Arg-Arg-Arg-Ala-His-Gln-Asp-Ser-	background	65
-Arg-Gln-Arg-Arg-Arg-Ala-Pro-Pro-Asp-Ser-	background	66

## EXAMPLE 9 - PRIMATE ANIMAL STUDY

A study was conducted in ten juvenile male rhesus macaques to determine if the presence of antibodies to Tat protein, induced by a synthetic peptide of this invention prior to infection with immunodeficiency virus, would attenuate infection and reduce levels of virus in plasma. HIV-1 does not infect monkeys, but a corresponding simian immunodeficiency virus (SIV) does. P.A. Luciw et al., Proc. Natl. Acad. Sci. USA, 92:7490 (1995) constructed an infectious recombinant virus (chimera) of SIV<sub>mac239</sub> and HIV-1<sub>SF33</sub> that does infect monkeys, typically causing an acute viremia that peaks around 2 weeks and subsequently subsides by week 8. In this chimeric construct, termed SHIV<sub>SF33</sub>, the SIV nucleotides encoding tat, rev and env (gp160) of SIV<sub>mac239</sub> have been replaced with the corresponding region of HIV-1<sub>SF33</sub>.

A. *Immunization of monkeys*

The monkeys were randomized into two groups.

Each monkey of group 1 (control group) was immunized with 0.4 mg diphtheria toxoid (Commonwealth Serum Laboratories, Victoria, Australia) with 0.25 mg threonyl muramyl dipeptide (T-MDP) in 0.5 ml water, this being emulsified with 0.5 ml MF75 adjuvant (Chiron Corp, Emeryville CA).

Each monkey of group 2 (test group) was immunized with 0.1 mg of the synthetic peptide Cys-Val-Asp-Pro-Asn-Leu-Glu-Pro-Trp-His-Pro-Gly-Ser-amide (SEQ ID NO: 84) coupled to 0.4 mg diphtheria toxoid (A. C. Lee *et al.*, Mol. Immunol., 17:749 (1980)). The conjugate was dissolved in 0.5 ml water containing 0.25 mg T-MDP and emulsified with 0.5 ml MF75 adjuvant.

Each monkey was immunized at day 0 and day 28 (week 4) with two 0.5 ml intramuscular injections at two distinct sites. The synthetic peptide immunogen contained the B cell Epitope I, Val-Asp-Pro-Asn-Leu-Glu-Pro-Trp-Lys-His-Pro-Gly-Ser- (SEQ ID NO: 115) of the Tat protein of SF33 HIV-1 that is incorporated in the SHIV<sub>SF33</sub> molecular clone that was used to challenge the monkeys (see above).

*B. Testing for antibodies to Tat protein*

At day 42 (week 6), 2 weeks after the booster injection, serums were drawn and tested by ELISA for binding to Ser-Gly-Ser-Gly-Val-Asp-Pro-Asn-Leu-Glu-Pro-Trp-Lys-His-Pro-Gly-Ser-OH (SEQ ID NO: 85), as described above in Example 1.

The control monkeys had background titers ranging from 25 to 44, while the test group had titers of 1788 to 9588, as shown in Table 24 below.

**Table 24**

CONTROL GROUP		TEST GROUP	
Monkey #	Titer	Monkey #	Titer
18782	30	18759	1788
18785	25	18789	5780
18786	30	18790	2718
18859	54	18863	4139
18908	46	18945	9588
GMT	35	GMT	4068

*C. Viral Challenge*

At day 49 (week 7) after initial immunization, all monkeys were given 1 ml of a 1/1000 dilution of animal titered SHIV<sub>SF33</sub> stock intravenously (challenge day 0). This corresponded to 50 animal infectious doses<sub>50%</sub> (50 AID<sub>50</sub>) or 200 tissue culture infectious doses<sub>50%</sub> (200 TCID<sub>50</sub>).

*D. Assessment of infection*

Plasma was drawn in EDTA at weeks 2, 4 and 8, and copies of viral RNA per ml of plasma were measured by QR-RT-PCR, using SIV probes for the SIV component of SHIV<sub>SF33</sub> (A. J. Conrad *et al.*, J. Acq. Imm. Def. Syndrome and Hum. Retrovirol., 10:425 (1995)). The results are summarized as follows in Tables 25 and 26.



Table 25

CONTROLS		SHIV RNA copies/ml plasma	
Monkey #	2 weeks	4 weeks	8 weeks
18782	880,000	30,000	<500
18785	610,000	80,000	<500
18786	500,000	50,000	<500
18859	22,000,000	120,000	<500
18908	20,000,000	100,000	1,000
GMT	2,596,851	67,869	

Table 26

CONTROLS		SHIV RNA copies/ml plasma	
Monkey #	2 weeks	4 weeks	8 weeks
18759	920,000	60,000	<500
18789	950,000	50,000	<500
18790	390,000	17,000	<500
18863	2,000,000	27,000	<500
18945	330,000	65,000	500
GMT	742,034	38,938	
INHIBITION: TEST VERSUS CONTROLS	71%	43%	

As expected, SHIV<sub>SF33</sub> caused an acute infection, with peak levels of viral RNA at 2 weeks and barely or non-detectable levels by week 8. Monkeys immunized with a synthetic peptide conjugate that induced antibodies to the Tat protein of the challenge SHIV<sub>SF33</sub> virus had, by comparison with control immunized monkeys, a 71% reduction in peak virus levels in plasma 2 weeks after viral challenge, with a 43% inhibition being still detectable in the subsiding plasma viral levels at 4 weeks. This shows that SHIV multiplication *in vivo* was inhibited in the presence of antibodies to the Tat protein being utilized by the virus, and suggests that a similar effect would prevail in HIV infected humans.

*E. Assessment of seroconversion*

Subjects infected with HIV develop antibodies to virion surface proteins and this is detected by ELISA and used to diagnose infection. Monkey serums were tested prior to virus challenge and 8 weeks after challenge, using the HIVAB®HIV-1/HIV-2(rDNA)EIA (Abbott Labs, IL). All pre-challenge serums were negative and all 8 week post challenge serums were positive. These findings provide additional support for the fact that antibodies to Tat protein do not register in diagnostic assays for HIV seroconversion.

EXAMPLE 10- PRIMATE ANIMAL STUDY

An additional monkey study was performed using immunization with synthetic peptides coupled to diphtheria toxoid (9 monkeys) or diphtheria toxoid immunized controls (5 monkeys). Initial immunization was with Freund's complete adjuvant, with boosts at 3, 6 and 9 weeks with incomplete Freund's adjuvant. The immunizing peptides were Cys-Val-Asp-Pro-Asn-Leu-Glu-Pro-Trp-Lys-His-Pro-Gly-Ser-amide (SEQ ID NO: 116) (Epitope I) and Cys-Arg-Gln-Arg-Arg-Arg-Ala-Pro-Asp-Ser-Ser-Gln-Asn-His-Gln-OH (SEQ ID NO: 117) (Epitope III).

Monkeys were challenged with 50 AID<sub>50</sub> of SHIV33, as above, 2 weeks after the last boost with immunogen. Geometric mean titers at 11 weeks (time of challenge) in immunized animals were 46,000 for Epitope I and 5,000 for Epitope III.

Geometric mean plasma viral loads at the peak (2 weeks) were 456,000 for the test group and 234,000 for the controls. However, from 4 weeks post challenge on viral loads in the test group dropped significantly below those in the control group (Table 27).

**Table 27**

	<b>Week 4</b>	<b>Week 8</b>	<b>Week 12</b>	<b>Week 16</b>
GML Viral load -controls (# negative)	17,000 (0/5)	900 (0/5)	400 (0/5)	120 (1/5)
GML Viral load - tests (# negative)	5,000 (0/9)	300 (0/9)	8 (6/9)	4 (7/9)
% inhibition	71%	67%	98%	97%

Seroconversion to SIV positive occurred at 4-8 weeks. Thus the post seroconversion viral loads (the most significant prognostic marker in HIV-1 infection) were significantly lowered in the presence of antibodies to HIV-1 Tat protein.

In an effort to understand the high peak viral load at 2 weeks in the test group, scrums were tested at the time of viral challenge (2 weeks post the last immunization) for TNF $\alpha$  by ELISA. TNF $\alpha$ , which is released during an immune response, activates cells and is known to by-pass the requirement for Tat mediated activation to support HIV-1 proliferation. The inventor determined that whereas serum TNF $\alpha$  was undetectable pre-immunization, it was detected in all Tat immunized monkeys 2 weeks post immunization with a mean level of 7 pg/ml.

It was concluded that the effects of Tat interdiction on the acute infection were masked by the peri-immunization TNF $\alpha$  activation; once this subsided, the Tat immunized group developed significantly lower viral loads, with the majority having undetectable (< 100 copies/ml) levels in plasma.

# EXAMPLE 11 - METHOD AND KITS FOR DETECTING TITERS AND SPECIFICITIES OF ANTIBODIES INDUCED BY VACCINATION

To follow the titer and specificities of antibodies induced following immunization with the vaccines of this invention, an assay method may be employed.

5 In one embodiment of such as assay, peptides containing the sequences reported in Table 28 (depending on the composition of the immunizing vaccine) are used to develop kits measuring titers and reactivity patterns of antibodies in vaccinated subjects.

**Table 28**

Epitope	Sequence	SEQ ID NOS
I	-Glu-Pro-Val-Asp-Pro-Arg-Leu-Glu-Pro-	(amino acids 2-10 of SEQ ID NO: 1)
I	-Glu-Pro-Val-Asp-Pro-Lys-Leu-Glu-Pro-	118
I	-Glu-Pro-Val-Asp-Pro-Ser-Leu-Glu-Pro-	119
I	-Glu-Pro-Val-Asp-Pro-Asn-Leu-Glu-Pro-	120
15 II	-Lys-Gly-Leu-Gly-Ile-Ser-Tyr-Gly-Arg-Lys-Lys-	(amino acids 41-51 of SEQ ID NO: 1)
III	-Arg-Arg-Ala-Pro-Pro-Asp-Ser-	(amino acids 266-272 of SEQ ID NO: 3)
III	-Arg-Arg-Ala-His-Gln-Asp-Ser-	121
III	-Arg-Arg-Ala-Pro-Gln-Asp-Ser-	19
IV	-Ser-Gln-Thr-His-Gln-Val-Ser-Leu-Ser-Lys-Gln-Pro-	122

20

These peptides are synthesized with Biotin-Ser-Gly-Ser-Gly- (SEQ ID NO: 123) at the N-terminus. Each peptide is coated onto separate avidin coated plates, with a sequence -Ser-Gly-Ser-Gly- (SEQ ID NO: 30) serving as a spacer to ensure that the relevant peptide sequence is external to the biotin binding pocket of avidin. The plates are then incubated with dilutions of test serum, washed, and the antibody binding determined with reagent to human immunoglobulin, e.g., rabbit anti-

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human immunoglobulin, bound to, e.g., biotin, or directly labeled with enzyme. An avidin-enzyme complex is used to detect the biotin label, or a reagent employed to react with the enzyme and produce a colorimetric signal (R&D kit inserts).

5                    Numerous modifications and variations of the present invention are included in the above-identified specification and are expected to be obvious to one of skill in the art. Such modifications and alterations to the compositions and processes of the present invention are believed to be encompassed in the scope of the claims  
10                    appended hereto.

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